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THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

APRIL, 1961 Vol. 51, No. 8

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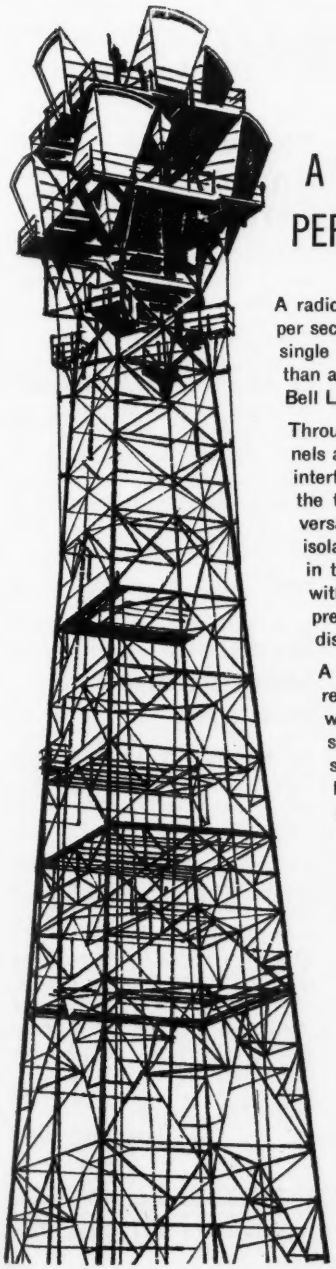

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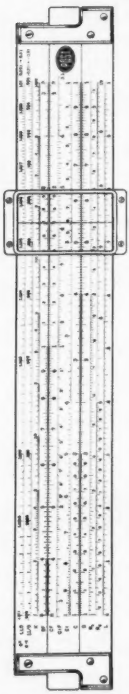

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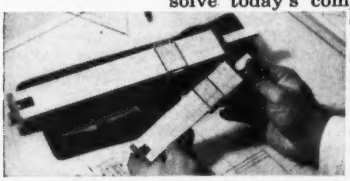

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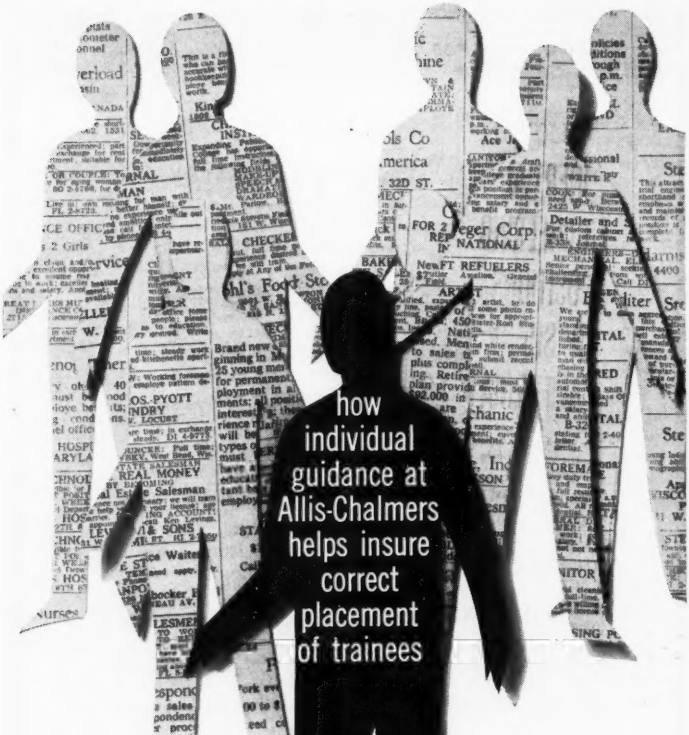

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Do You Know

► That in the annual report of one of the engineering societies the statement is made that the ratio of headquarters staff to membership continues at a low figure of slightly less than 2 employees per 1,000 members? It is further stated that this low ratio is impressive when it is realized that the year just closed witnessed increases in the areas of headquarters activity and member services. The same ratio under the same situation, for ASEE is 0.81! Is ASEE's staff low because the services are low because the dues are low, or are the services low because the dues are low because the staff is low, or are the dues low because the staff is low because the services are low? Or do you have some other idea?

► That membership in ASEE and the subscription to the JOURNAL OF ENGINEERING EDUCATION going with it is the cheapest dues-subscription combination in engineering except for two other societies? These data come from "Cost of Society Journals to Members and Nonmembers of Scientific Societies in 1959" published by the National Science Foundation. The two societies below ASEE are the Association for Computer Machinery and the Audio Engineering Society. Twenty of the 52 societies reporting charge extra for their journal, and 14 of the 52 societies have higher subscription costs to non-members than ASEE. Six of the 52 societies, including ASEE, charge more for a subscription to the magazine by non-members than "dues and the journal" costs members. Ten dollars and over is charged for dues and publications by 44 societies, and 34 socities charge $15.00 or more. Of a total of 217 societies considered, only 43 charged less than $8.00 for the dues-publication combination and 21 of those were among the 66 organizations in biology. The average cost of dues-subscriptions for the 52 engineering societies is $18.00 per year. The report also makes a comparison of the median annual dues and median annual salaries by discipline for the areas of biology, mathematics, earth science, physics, social science, chemistry, miscellaneous, and engineering. Both vary in the same general order except for the median salaries for social science, and miscellaneous. Biology is the lowest with median annual dues of $6.00 and a median annual salary of $6,789. Engineering is the highest of all with median annual dues of $18.00 and a median annual salary of $9,065. It is believed that copies can be obtained from the Office of Science Information Service of the National Science Foundation.

► That a summer institute on "Nature and Properties of Materials" again is being supported by ASEE for the summer of 1961? Just as for last year, the 6-week program is being given by Iowa State University. The National Science Foundation provides funds under its program of summer institutes for college teachers. Promotional literature has been mailed to deans of engineering, directors of research, and department heads. Direct inquiries should be sent to Dr. Glen Murphy, the Director of the project.

► That reprints of "General Education in Engineering Curricula: Old Issues and New Developments" are available for 25¢ each? The papers were published in the November 1960 issue of the JOURNAL and constitute a follow-up of the 1956 report on General Education in Engineering. The papers are the ones presented at the 1959 summer school sponsored by the English Division and the Division of Humanities and Social Sciences. Orders for copies should be directed to ASEE headquarters.

► That "Research Relations between Engineering Educational Institutions and Industrial Organizations" may be purchased from the Superintendent of Documents, Washington 25, D. C., for 25¢ a copy? This is the booklet prepared by ECRC and published by the Small Business Administration a year or so ago. The booklet was distributed by SBA, but it seems worthwhile to call the attention of those engaged in research to the booklet in order that they can promote its reading among the companies with which they have contact.

► That a report on salaries and income of engineering teachers for 1960 is now available? Copies may be purchased for 25¢ each from either ASEE or EJC. The average total professional income of engineering teachers increased by 14.7% in the past 2 years. About ¾ of this increased income is basic teaching salary; the remainder is derived from outside professional work. The average basic teaching salary is $8,534 and is supplemented by an average of $2,479 from outside professional income. The median teaching salary for instructors is $5,380. You will have to read the report to find the similar value for full professors. The survey is the result of a cooperative project of the Engineering Manpower Commission of EJC and ASEE and is an adjunct to the survey of professional income of all engineers which can be obtained only from EJC for $3.00 per copy.

► That the University of California at Berkeley is offering a correspondence course to aid engineers to prepare for professional registration examinations? The course is entitled, "Engineering Fundamentals" and was developed after 100 examinations utilized by 35 states were analyzed over a 3-year period of time. The course is designed to be of benefit to all engineers preparing for the first, or closed book, portion of the engineering registration examination in any of the 50 states or 3 territories. The course is also aimed at engineers who wish to review fundamentals as an aid to current work or in preparation for advanced study. For information and enrollment write to Department of Correspondence Instruction, University Extension, University of California, Berkeley 4, California.

► That Assistant Secretary Jimmy W. Seyler now has a new assignment for the other 50% of his time? Since February 1, he is no longer teaching courses in construction in the Department of Civil Engineering of the University of Illinois. Instead, he is devoting his time to the coordination of and improvement of extramural instruction for the College of Engineering. This appointment establishes the responsibility for the administration of the engineering courses in the hands of an engineer.

► That a brochure listing the nuclear education programs in the United States has been published by the Oak Ridge Institute of Nuclear Studies? For each of the 175 schools offering instruction in nuclear fields, the 76-page booklet lists degrees, courses, facilities, and availability of fellowships and assistantships. Additional tables list institutions with plasma and thermonuclear research facilities, particle accelerators, and gamma radiation facilities. Existing or planned university reactor installations are indicated according to type. The B.S. degree, only, is offered by 3 schools; two offer the B.S. and M.S.; and 4 offer the B.S., M.S., and Ph.D. The M.S. degree only is offered by 28 institutions, and 19 offer both the M.S. and the Ph.D. None offer only the Ph.D. This means that a student can get a B.S. degree in Nuclear Engineering at 9 schools, the M.S. at 53, and the Ph.D. at 23. There are, of course, many institutions at which work in nuclear engineering can be gotten as part of curricula leading to the more traditional engineering degrees. Copies of "Education Programs and Facilities in Nuclear Science and Engineering" are available free of charge from Education Programs and Facilities, University Relations Division, Oak Ridge Institute of Nuclear Studies, P. O. Box 117, Oak Ridge, Tennessee.

► That *Graduate Education in the U. S.* is a new book many will want to read? It brings out that the 12 institutions having the largest number of articles contributed by their faculties to America's leading academic journals have only 10% of the nation's college faculty members, but account for almost 40% of the authors in the journals. The recent recipients of the doctorate degree from the 12 institutions also have contributed one-third more publications to learned journals than those from other institutions. The author is Bernard Berleson of Columbia University and the publisher is McGraw-Hill.

► That "Air Pollution and Smog" is a 20 page booklet giving an understandable, accurate summary of the present state of knowledge about air pollution?

Copies can be obtained from the Air Pollution Foundation, 2556 Mission Street, San Marion, California, or from the Air Pollution Control District, County of Los Angeles, 434 South San Pedro Street, Los Angeles 13, California, apparently at no cost.

► That "Selected Bibliographies on Topics Related to Current Engineering Educational Philosophies and Instruction in Experimental Mechanical Engineering and Design Courses" has been prepared by the Department of Mechanical Engineering of Lehigh University? The Interim Report of some 55 mimeographed pages results from a project sponsored by a grant from NSF; no claim is made for its completeness and no conclusions have been drawn.

► That American industry employed approximately 640,000 engineers in January 1959? The number of scientists employed was about 160,000. These figures are based on the returns from 47,500 firms and extrapolated to include those self-employed or on the staffs of small firms. Engineers and scientists comprise about 3% of the work force of the industries covered; the high was 11% in aircraft manufacturing and the low was 0.3% in textiles and apparel. In manufacturing industries companies with 5,000 or more employees accounted for nearly two-thirds of the engineers and scientists but only two-fifths of the total work force. Research and development was the primary activity of about 36% of the total, 31% doing it and 5% administering it. Work connected with production and operation claimed 39% of the total, exclusive of those administering such activities. The rate of increase in employment was less between 1957 and 1959 than between 1954 and 57; the largest gain was in R & D. These data come from the NSF report "Scientific and Technical Personnel in American Industry," available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. for 45¢.

► That J. N. Landis, Vice-President of the Bechtel Corporation, is the new President of EJC? Mr. Landis is a mechanical engineer who once served as a mathematics instructor at the University of Michigan and now is vice-president of the Bechtel Corporation of San Francisco. G. E. Holbrook was re-elected vice-president; he is a chemical engineer and is a vice-president of E. I. duPont de Nemours & Company.

► That Dr. Logan Wilson, now Chancellor of the University of Texas system, is to be the new President of the American Council on Education? Dr. Arthur S. Adams, who has been president for the past 10 years, is retiring in the spring of '61. Dr. Wilson had been president of the University of Texas since 1953 and was named chancellor of the University of Texas system of higher education earlier this year.

► That the President of the American Council on Education has sent a letter to the presidents of its institutional members commenting on an "academic double standard?" The difficulty stems from the fact that some American institutions have been less rigorous in their demands on students from foreign countries than on American students. When American colleges and universities admit, grant advanced standing to, or award degrees to foreign students by standards lower than those applied to American students, they follow a practice which, rather than improving international relations, actually has an adverse effect on the reputation of American higher education in other countries. Since so many foreign students are engineers it behooves all of us to give serious thought to this situation.

► That "Teaching Positions Available" does bring results? The following letter has just been received, "Just a note to tell you that our advertisement in the November and December issues of the JOURNAL has produced excellent results. We have had a number of applicants, and have filled the vacancy which we had sought to fill." It is always nice to know that services offered by the Society bring results and are appreciated.

W. LEIGHTON COLLINS
Secretary

Is Sponsored Research Destroying Our Universities?

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Summary

In Chapter I we shall be concerned with the definition and function of a university, and the definition of sponsored research to be used in this discussion. Chapter II will present the university problem which makes sponsored research an attractive solution. Chapter III will attempt to disclose the defects in the sponsored-research solution and the consequences in the life of the university. Chapter IV will briefly discuss alternate solutions to the university problem developed in Chapter II.

My treatise will make no attempt at erudition. I shall not trace the history of the ideas, nor attempt to give due credit to those who had a substantial influence on my thinking. Perhaps it will help if I renounce all claims to originality—and permit anyone to use a part or all of my treatise without acknowledgment.

Chapter I: Concerning Definitions

A university is composed of a group of people and an agglomeration of physical facilities, all organized to perform a particular service for society. What is this service? Primarily, it is to train our young people to live in, or at least in reasonable harmony with, the world of ideas. Certain skills are necessary for meaningful participation in this world (language, logic, and others), and the physical and mental health of the students should be maintained. For how can one give primary concern to ideas unless a certain minimum level of health is first met? But we should never lose sight of the university's world as the world of ideas.

Although the teaching function as described above is the primary service a university renders to society, there is another service closely coupled with it, namely, the generation of new ideas. It is no surprise that the faculty of any university worthy of the name, a member of which must acquire mastery in working with ideas in order to teach effectively, will produce new ideas. The production of new ideas is known as research. History has shown that institutions of higher learning have always been centers of research.

It will serve little purpose to attempt an answer to the question, "Can a university perform its teaching function without research?" Let us accept the dual function which society has identified with the university, namely, teaching and research. As long as we accept the research function as vital to the business of a university, and I know of no serious thinker who believes otherwise, we have achieved the first step in our discussion.

At this point I wish to depart from general considerations and develop the discussion of university objectives only as these objectives apply to the limited area of science and technology, where we concern ourselves with material, or physical, things. In particular, I wish to discuss the difference between the teaching and research functions of the physical science areas of a university and of industry.

For industry also has vital teaching and research functions. Is there any difference between these functions in industry and in the university? If we recognize that industry depends for its existence on the comparatively short-range return on its investment, we shall understand that its teaching and research functions are properly directed

toward comparatively short-range goals. Its teaching is directed primarily toward skills, and its research toward limited goals. The research technologist in industry is often given a large degree of freedom to pursue his investigations, but he is always conscious of the pressure that the company's investment in him must someday "pay off," and he suspects rightly that after a reasonable period of time (perhaps two to five years) his salary and other conditions of employment will be influenced by his clearly established contributions to the company's business.

A technologist who concerns himself with long-range research will seek an atmosphere of greater freedom than is found in industry. He must better "understand" the various principles and rules which he uses, in order to apply new solutions to old problems. The important advances usually come as the result of much work which appears to be idle speculation. Such speculation is directly related to the measure of freedom which an individual enjoys in his work.

If the university is to perform a unique function in technological research, it would appear that this function can only be performed by providing an atmosphere of great freedom. That this same atmosphere is necessary if a university is to perform its other functions in society will not be developed here. The point has been well summarized by President A. Whitney Griswold of Yale University in a recent article concerning loyalty oaths: [1]

"Underlying this concern with test oaths, in fact underlying the whole position of the colleges and universities in this controversy, is their concern for freedom. For centuries, in Europe as well as England and America, they have struggled for the right to pursue learning for its own sake without interference by church or state. They have done so not because they thought society owed them this right as a mark of respect or a special privilege, but because they have regarded it as a functional necessity identical with freedom of the press and similar to freedom of speech, freedom of religion, and freedom of assembly."

I would like to place the emphasis on the words "functional necessity." If the university is to perform its function in society, it must have an atmosphere of freedom: freedom to generate and discuss unpopular ideas, freedom for idle speculation, freedom to pursue ideas entirely unrelated to the current values placed upon them by society. Of course, no freedom is absolute, and freedom does not of itself assure a university success in its function. But if we recognize that every curtailment of freedom brings with it a reduced potential for the university's service to society, we will understand that the educator who seeks to serve his community must be deeply concerned about any policy, law, or regulation which acts, intentionally or otherwise, to reduce the freedom of the university atmosphere.

The university's function, therefore, is not merely to provide a center for teaching and research, but to give its attention to that portion of teaching and research which has a long-range perspective. For technological research, the university must be concerned with ideas which may have economic value 10, 20 or more years from now. These are not usually ideas in which the business man will make an investment. He has many pressing short-range problems, and, besides, the free atmosphere of a university makes for wide dissemination of its research findings which, when coupled with generality (that is, wide applicability) of the results, usually reduces the competitive advantage he might gain from his investment.

That the proper functioning of a university requires freedom is a generally accepted position. Tenure is an instrument by which a university staff member who has previously shown himself to be a responsible individual is protected to some degree against unfavorable reaction brought on by the espousal of an unpopular opinion. Yet the high value of freedom, when a part of it must be traded for money, buildings, tem-

[1] "'Loyalty': An Issue of Academic Freedom," *New York Times Magazine*, December 20, 1959.

porary prestige, or direct social services, as it always must be, is not properly appreciated by many educators, not to mention others in our society. In certain compromises, even if the high value of freedom is understood and the "deal" is made with the best of intentions, there are well-concealed traps which exact a costly price in the service performed by our educational institutions.

By contract research I am referring to the work done within a university, by university personnel, as a result of an agreement between the university and an individual or group of individuals outside the university. This agreement has the following characteristics:

1) The contract is always based upon a proposal submitted by an individual staff member or a group of staff members within the university. Since the proposal is almost always a careful exposition of research objectives, methods, and costs, the central individuals in proposal preparation are the research investigators who will be in responsible change of the work. Occasionally, the negotiations leading to a proposal are initiated by the eventual sponsor, but the usual procedure calls for the staff member to be aware of possible sources of support and to open negotiations leading to an acceptable proposal.

2) The contract calls upon the university to pursue its research activities in certain specified areas, the areas of direct interest to the outside group (sponsor). This area of interest is usually narrowly defined: elimination of diesel engine noise, characteristics of rubber vibration-absorbing mountings, de-icing of aircraft windshields. Rarely is the area as broadly defined as "study of vibrations in an elastic solid."

3) A time limit for the contract activity is specified, which is frequently 1 year, sometimes as long as 3 years, and very infrequently 5 years.

4) The sponsor agrees to reimburse the university for direct costs (consisting of the pro-rated salaries of individuals engaged in the contract, the out-of-pocket costs for use of research facilities, expenses for materials and apparatus) plus an additional sum for "indirect" or "overhead" costs. This additional sum is commonly around 50% of direct costs, although the figure varies between 0 and 100% and depends upon how the direct cost is calculated.

5) A final report is always required, and the sponsor usually contracts for certain rights on any patents that may result from the research. Progress reports at stated intervals are usually specified. The reports are sometimes restricted with respect to dissemination of the research findings. One highly-esteemed research group grants its sponsors the restriction that presentation of research results outside the immediate membership of its group will be withheld for one year after the report is completed. The restrictions to which I refer apply to other than government-sponsored work in classified areas, which poses a special problem to universities not treated in this discussion.

Chapter II: Financing

Today's financial pressures on the university are severe. They arise essentially from the rapidly changing society of the past 2 decades, bringing its new perspectives to bear upon a social institution not designed for responsiveness to rapid change. Endowments represent slowly-changing income in an age of rapidly rising costs, costs which in part reflect the need for expensive new research tools and in part the rise in salaries created by the great demand for skilled scientific-technical personnel outside the university. Furthermore, to meet the current needs of our society our educational plant will have to be expanded to meet a large increase in student population. Where will the money for large capital expenditures be obtained? This is a particularly difficult problem for universities because they have no reserves for replacement of worn-out physical facilities and have not included depreciation as an item in educational cost. Thus, operating on the principle that contributions will be obtained for a new physical facility when the old one is clearly worn out and beyond all possible effective use, the universities must now obtain capital funds to supply not only the new facilities needed by the new age, but also to replace obsolete equipment for which replacement provisions could have been, but were not, made.

I shall make no attempt to present a detailed documentation of the increase in educational costs in recent years. An estimate, based on very limited knowledge, is that the cost of educating a

scientific-technical student for 1 year has approximately doubled in the past 10 years. We do not need a more accurate figure to support the position that the pressures for increased funds are large, not small. Where will these funds come from?

The answer offered by many, "contract research," looks attractive from many points of view. Government and industry need the technical-scientific help that professors are qualified to supply. Large funds are available to solve difficult problems. Why should the university not undertake work on these problems in exchange for badly needed funds? But the attractive aspects are not limited to funds alone.

Additions to the staff need to be made to carry the new contract obligations, which bring new blood to the university. Furthermore, those new staff members can be attracted with high salaries, if they undertake contracts, because they will be employed during summer and other "vacation" periods. In some schools, where the normal academic week is traditionally considered as 4 days plus a fifth spent on personal activities including industrial consulting, a contract researcher may receive a 25% increase in base salary for spending the fifth day on contract work. A high salary, plus the attractions of an academic environment, make for a substantial inducement to technical research personnel.

Contracts also provide a means for stimulating faculty members whose thinking has not kept up with progress in their fields. By accepting convenient employment under conditions financially attractive to them, they are often brought face-to-face with current problems. In the case of older men in tenure positions whose knowledge is no longer sufficient to teach a full roster of courses, because to require this would lower the standards of instruction to an unacceptable degree (a situation caused by the normal inertia of individuals and the rapid technological change of the times), the need on contracts for much good technical work not at a high research level provides an opportunity for useful employment to fill such a staff member's work schedule.

Contract funds also provide means for support of students, particularly graduate students. It has been accepted that graduate students in a day program, unlike undergraduates, cannot be expected to provide their own subsistence funds. The reasons are clear: the bright young scholar and his family practically never set their financial sights on goals beyond the bachelor's degree (indeed, the undergraduate expenses are often more of a burden than they can bear alone), and the young man is reluctant to undertake a heavy debt at the start of his professional career. If a promising young graduate is not provided with tuition and subsistence by the university for continuing his studies, he will seek industrial employment and pursue graduate studies on a part-time basis. Such a course, while superior to abandoning all further study, is nevertheless a severe handicap to serious scholarship and a practically insurmountable one for the intensive effort required of a scholar at the Ph.D. level.

It is usually better for a graduate student to earn his subsistence by employment on university activity, teaching or research, than in outside employment, if the pay rates of the university are not too much lower. With contract funds the university can arrange employment for graduate students. Often the contract involves work closely related to some problem which will be suitable for thesis research. Thus the student may find that his academic research requirements and his subsistence funds are both supplied by a contract.

Research equipment, another major financial burden of a university, is obtained through contracts. Sometimes the school receives full title at the end of the contract period to equipment purchased with contract funds. Sometimes the sponsors retain title but permit the school to use the equipment until other disposition is made. In some instances bids for the equipment are solicited by sponsors after the contract period and the school obtains title to the equipment at a very modest cost. In

any event, the university obtains use of valuable research equipment at least for the contract period, with the resulting educational opportunities furnished to staff and students.

We see, therefore, that an imposing list of advantages accrues to those who follow the sponsored research path. Allowances for "indirect" costs support the operating budget, new graduate students and staff are attracted, year-around activity is generated, many research papers are published, new research facilities and equipment make their appearance.

Is it any wonder that many people, both inside and outside the university, see contract research as the answer to their problems? To a school that is rapidly trying to build up its technical-scientific area, perhaps partly to meet its social responsibility to educate an increasing number of scientists and engineers, is there any other way? A colleague of mine recently put it in the following words: "You must accept contract research; otherwise you are just not in business today."

Chapter III: The Price We Pay

Let us take a careful look at the activities of the professor who engages in project research. First, he is not only encouraged by administrative officers to submit his research ideas in the form of proposals to prospective sponsors, but is offered the help of administrative advisers who will assist in preparation of budget and contract specifications. This is an important service because the maze of routines to be followed (most of the fund sources have different standards for proposals) and the mass of background material to be digested for calculating direct and indirect costs would take much time.

The professor has a graduate student who has expressed interest in pursuing the particular problem for which the proposal is designed. The budget would appear to be simple: one calendar year of subsistence funds for the student ($2,000) plus the cost of electronic digital computer time. No experimental equipment is involved. How much computer time will be needed? Well, that's not easy to predict, but let it be estimated that 20 hours of a high-speed machine such as a Univac *I* will be sufficient. The student will do his own programming. At $300 per computer hour this adds a budget item of $6,000. (This charge presumably includes overhead, because the hourly figure represents the market price to all comers.) Thus the budget total is $8,000.

The professor is surprised, however, when the proposal is returned to him by the university administrative advisers with a budget total over $20,000. A portion of his own time as "principal investigator" has been charged, expense items are included for secretarial help, travel funds for technical meetings and conferences. Then an "overhead" factor is applied. These operations, the professor consoles himself, are no doubt the normal procedures and result from accounting intricacies beyond his understanding. Yet he cannot easily dismiss a suspicion that it does not take $20,000 of sponsor money to do an $8,000 job and that perhaps he might unwittingly become the central figure in an unsavory business deal. Perhaps he should not so quickly accept the help of the business "experts" in preparing the proposal. But then, how would he be able to devote the needed personal time to the matter without sacrifice to his scholarly efforts?

Professor X may be successful in landing his contract, or he may not. Usually he needs to apply to a number of possible sponsors before the project is accepted. Furthermore, it is normal practice to determine what areas of research will be of major interest to sponsoring groups and to orient the proposals accordingly. To do this, Professor X needs to become acquainted with the individuals who decide upon the distribution of funds. All this takes time.

Thus we see that Professor X must spend considerable time in writing and re-writing proposals and in becoming familiar with the policies and men in prospective sponsoring groups. If he is a man of recognized high professional standing, this process is somewhat easier

than for the young man struggling for professional recognition. By this very fact, however, the pressure for obtaining research sponsorship falls increasingly upon the established professors.

Let us assume that Professor X obtains his contract. His graduate student, assuming he is still available after the months of proposal preparation, submission, and negotiations, embarks upon a year of concentrated doctoral research. Professor X as "principal investigator" must now take official responsibility for his work. If the student is able and diligent, a good result may be expected. If the student is lazy or careless, or decides he wants to work on something else, the professor is in a delicate situation. In the normal course of graduate research, with responsibility upon the student, the consequences of failure to do the work are a burden primarily upon the student. Now the professor takes the burden. To maintain a reasonable "credit rating" among sponsors it may be necessary for him personally to direct the research or to write the final report (thesis). Is this shift of responsibility from student to professor a good thing educationally?

If Professor X continues to operate in this way, he is using sponsored funds under optimum conditions. He will provide sponsored support for students only if his project proposals are accepted as technically specified, on the basis of his own free will. If there is no support, his graduate student research activity will be restricted to that of students on fellowship or on part-time employment elsewhere. Since the fellowship group is small, and the part-time group necessarily must make slow progress, graduate activity with Professor X is limited, at least in quantity. Professor X is unhappy about the price he pays in promotional effort, feels that the shift of responsibility from the student's shoulders to his is educationally unsound, deplores the hand-to-mouth character of support for a long-term research program.

But he is in a much better position than Professor Y, who operates on a larger scale and who is currently the darling of many university administrations. He has a number of contracts (mainly from government agencies), maintains a research laboratory with at least 1 full-time expert mechanic, has 3 students engaged in doctoral research and 5 or 6 lower-level graduate students employed as helpers. Other staff members, colleagues of Professor Y, may also have part-time assignments with the group.

Not only does he face the problems of Professor X, but in addition Professor Y faces the pressures of big business. The university cannot afford to give financial guarantees to Professor Y to assure the continuance of his operation in the event of loss of his contracts. Since it is at best very difficult, and possibly unethical, to cancel the employment of students and staff when funds run out, not to speak of the problem of hiring and firing of the needed expert mechanics, the pressure on Professor Y to obtain contract renewals or replacements is very great. He will try to get contracts for the research of primary interest, but he soon begins to settle for less. There come times when he will take any work, including routine industrial testing, to keep the doors of his laboratory open. The late Dr. Max Jacob of the Illinois Institute of Technology, world-renowned for his work in heat transfer and thermodynamics, once confided to me, in discussing his contract-supported operation, "Never did I think that in my old age I would become a business man."

That is precisely what Professor Y has to become: a business man. Scholarship and teaching are secondary. What do professors think of becoming business men? One harrassed individual remarked sourly, "It wouldn't be so bad if the calls from Washington wouldn't get me at home before breakfast." Another, obviously more prominent than most of us, offered this: "If I have to run a business I'll set up my consulting office across the street and make $50,000 a year." Both are dedicated young members of a university teaching staff.

Increasing dissatisfaction with a system in which the staff member is "encouraged" to do "research" (defined

as contract activity) is driving many promising young teachers into industry. The full professor of established reputation may be able to isolate himself in his own academic climate (not a happy prospect), but the young man on lower rungs of the academic ladder sees only slow advancement as the price of resistence to sponsored research. He looks with interest to industrial research positions which will pay him twice his academic salary for work which is no more restrictive than the contract research business.

The professor who refuses to engage in contract research finds additional pressure for conformity. It is made clear to him that he is not "pulling his load," since others are helping to support his operations with funds from contract "overhead." He finds that graduate students are attracted to research areas where contract funds are available for their support. Support for his work from general university funds is not available, except for the few fellowship students and limited special research funds, partly because administrators want him to seek contract funds, partly because a commitment to a sponsored research policy discourages contributions from other sources. ("The engineers can get contract funds; let's give our money to a more needy group.")

We see, therefore, that a policy of contract research definitely acts to focus activity on areas for which contract funds are available. The sponsor with funds calls the tune. Is the sponsor's primary interest the long-range research which must characterize university activities? In spite of many protestations to the contrary, the answer is, "No." There are times when business or government will provide funds with almost no restrictions, but the hard realities of their short-range needs are never far beyond the horizon. In any event, permitting control of university research activity to rest with organizations outside the university is an abdication of the university's responsibility to society.

In brief, we may sum up the price of a contract research policy as running the university as an industrial research organization. I suspect that it does not take a very high level of contract activity to reduce the teaching function to a peripheral activity. Can tenure be maintained if the academic staff is twice the size it would be if no contract research existed?

The tenure problem deserves a few words. If tenure crumbles, many will consider the price to be high. Already it is becoming the practice in some institutions (I do not know how common this is) to employ some staff members at top professorial levels, presumably to be engaged largely in research, on the basis of limited or restricted tenure. The reason is to protect the university in the event of contract support failure, permitting release of the staff member without tenure complications. With contract research calling for men who would qualify for top tenure-carrying positions in a university, with the university having only short-range financial support for a substantial number of the staff, the pressures on a university are considerable to release itself from the shackles of tenure.

Perhaps the *real* measure of the price to be paid for contract research is indicated by the attack on tenure.

Chapter IV: Conclusions and Suggestions

Is it too much to say that a university will cease to exist when academic research is destroyed? I think not. I have tried to show that present sponsored research practices, with their high cost in freedom, are forcing a change from the long-range perspective, which must characterize university research, to the short-range goals of industrial and military activity. In a time of national emergency perhaps the emphasis on short-range goals can be justified, but should we consider ourselves now in such a time?

The university is a durable institution. It will surely withstand even heavy blows for many years. Sponsored research is not likely to destroy the university if its dangers are uncovered. Groups both within and outside the

university will then act to remove the threat. Rejecting the sponsored research solution to the financial problem throws us back to our starting point. How will the university pay the bill?

It is clear that the university will have to be careful about the means which it chooses. Society will not be served, at least not very well, if universities either choose, or are forced by lack of other solutions, to place slot machines in the halls, to operate a profitable entertainment business in the form of semi-professional intercollegiate sports, or to accept sponsored research.

Perhaps the real issue is not that the university faces destruction from a bad choice of solution to its financial problems, but rather that it may become an ineffective servant of society. It would be a sad commentary upon the richest nation the world has ever seen, that it could not afford to maintain its universities at a high functional level.

The traditional main sources of financial support of a university have been tuition, endowment income, direct government subsidy, and gifts from private individuals and organizations. It is probable that each of these sources will have to be developed in a new manner to meet our modern needs. To solve the short-term problems of the university's financial need it would seem that Dr. Robert M. Hutchins' comment on a recent television program, to the effect that "massive intervention by the federal government in the next few years is inevitable" offers part of the answer.

It is possible that outside funds for the support of academic research may be offered in a form that will be constructive. Such support will not fall within the term "contract research" as defined in this discussion. The proper support will be characterized by one general principle: it will not to any significant degree influence the free formulation by the university of its research policy and the allocation of research funds in accordance with needs determined within, not outside, the university. In view of the pressures to accept funds of any kind, and the traps which these funds frequently carry with them, it is necessary that great care be exercised in specifying the conditions under which research funds be accepted. The following specific suggestions are made with the objective of assuring university control of academic research activity:

1. The scramble for research funds by a professor's writing proposal after proposal must end. If a prospective donor wishes to put his funds to academic research use, he should find out where such funds are best spent by brief personal visits, primarily for interviews with the university staff, and by study of the qualifications of an institution and its members. Brief interviews will not be a major distraction to the professor.

2. Research grants should be a direct donation to the university, without any conditions whatever. The donor may make suggestions, and these would undoubtedly be considered by the university professorial committee distributing the funds, but the decision on how to use the funds (within the broad meaning of research) must be made inside the university.

3. If the first 2 suggestions are accepted, all other matters are secondary, since they depend upon internal university controls. The university will direct its research funds into long-range activity, maintaining the necessary continuity. It will specify the number and character of the reports, determine the procedure for cost accounting (what charge must the Computer Laboratory make to the Mathematics Department for time on a research problem?) and decided upon the proper practices for employing research assistants.

ANNUAL MEETING, UNIVERSITY OF KENTUCKY, JUNE 26–30

Impact of Engineering College Research on Graduate Programs and Faculty Development

Viewpoint of a Graduate Dean

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It is the wish of the program committee, I understand, that I be as provocative as possible in order to arouse vigorous reaction and discussion. I suppose this should not be too difficult for me, since graduate deans are said to be those deans in the university who have no budgets, buildings, curriculums, faculties or authority, and yet have provokingly strong views about them that they rarely hesitate to express. I am such a dean. To achieve this provocation, the first part of my paper will consist of a series of barbed questions without answers—except perhaps by implication. In this way I hope to call attention to some important problems and express some of my concerns. In the second part I shall return to the first two of my questions and present, rather dogmatically, some of my own views, to which you may want to take exception.

When I consider the effects of increasing research activities upon graduate work in engineering in the future, the questions that arise are legion. Here are some of them.

1. Will, or should, the augmented demand for research change the complexion of our faculties? By "complexion" I mean their competences and academic standards, their interests and activities, their relations with students, the quality of the courses and seminars they conduct, their scholarly output, their relations with industry and government, and still other important characteristics. And how is the complexion of our student bodies likely to change?

2. In view of such changes as we may anticipate, do our procedures for recruiting faculty and students need overhauling? Will our traditional standards and procedures turn out to be sufficiently selective relative to the accentuated demands of research?

3. Next, what will happen to our educational philosophy and practice at the graduate level? This has many diverse ramifications. To mention only a few, and a few that certainly are diverse, will the impact of research demands help some of us to see what we should all have seen long ago: that in graduate work formal courses are relatively unimportant; that the teaching of the ideas prevalent at the moment is also; and that in the university the most important result of research is the contribution it makes not to knowledge itself, but to the development of the student as a creative scholar upon whom we shall want to depend in the future for the new knowledge and methodology we shall need. And will our research ideals and competence carry over into our educational practice and determine it to a larger extent than it has in the past?

4. What will happen to our teaching? Will its quality suffer? Can professors be expected to give the proper amount of time and thought to teaching if they are also expected to carry on serious research? Will our faculties be split in the graduate school, as they are being split in many undergraduate colleges, into two camps, the teachers and the researchers? May it not be that if we

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grant that in the university the most important product of research is the student and his development, this ominous dichotomy will tend to disappear? Can teaching and research actually be separated in the graduate school?

5. Have graduate engineering faculties thought critically enough about the best way of training future researchers? How does one "teach" research—by means of courses about research or research methods, *or* mostly by example and contagion? What kind of research is appropriate, or inappropriate, for the training process, and therefore for thesis purposes? When may a graduate student be said to have "arrived" as an independent investigator and therefore be ready for the cognomen "doctor"? And if we confer the degree of doctor of philosophy should we insist on the candidate's really being a philosopher? Or can we claim to have given him the best training if he is simply a superspecialist or a supertechnician? Do we have an adequate rationale regarding such matters?

6. What will research itself come to mean? Will we think of it more and more narrowly, or more inclusively? Will the terms "graduate work" and "research" in engineering refer only to the basic sciences, or also to design? To general ideas and basic principles only, or also to specific products? Is it indisputable, as is often asserted, that the art of engineering, as distinguished from its science, is beyond the pale of respectable graduate education?

7. Is it possible that the realities of the research enterprise will lead us to organize our universities differently? A research project today is typically interdisciplinary, and often so extensive and yet so dependent upon the close meshing of all its components that all participating investigators must be competent far beyond the boundaries of any one traditional field. It congregates people who work together so closely that they develop more interest in their common venture than in their native disciplines or departments. Moreover, it often requires the close collaboration and mutual understanding of engineering and science minds respectively. Can the university of the future properly support or domicile *such* enterprises and graduate work, if its basic organizational unit continues to be the traditional single-discipline department?

8. And what of the graduate school and the degree programs it provides? Already in some universities the number of candidacies in broad interdisciplinary fields threatens to exceed those in the conventional "single" ones. And then there are the programs with radically different purposes, that are not conceived basically in terms of knowledge for its own sake, but, say, of social function. And may we not need new kinds of degrees to correspond more adequately to the variegated purposes of these newer programs?

9. Will the pressures of research sponsored directly by industry and government make us more conscious of our social responsibilities and opportunities? Increasingly the important problems confronting us in research emerge from the social situation, from the material and spiritual needs of people.

It is my observation that, within the university, concern for human values is at least as profound among engineering and other technological faculties as among those of the humanities and social sciences. By and large, however, this concern seems to be regarded as largely extraprofessional or extra-academic. May it not be that sponsored research, with its pronounced social orientation, will force upon engineering faculties a recognition of the need for more explicit curricular consideration of the social and moral dimensions and obligations of engineering?

10. How long can the ivory tower concept of the university persist in the face of such developments? And the insular idea of the faculty as a sheltered and relatively independent community of scholars? Somewhere I have heard of the "diffused university" that spreads out into society and is in turn penetrated osmotically from without; that takes as much of its activities as possible to the people where they are; with more and more of its scholars accepting responsibil-

ity extramurally, and with more and more extramural scholars and men of affairs contributing to its work and life internally. Is this tendency to be welcomed or not, by the university in general, and the engineering school in particular?

All the questions I have raised so far are challenging ones, in that they look ahead in a constructive mood calling for growth and adaptation to new situations. But others crowd in upon me also, jeremiads that stem from misgivings and fears, and a mood of conservation, and protective reaction. While admittedly these fears are rather conventional, I feel that I should not bypass them.

11. Is there danger that unsponsored, university-financed research may be submerged and stifled by the deluge of sponsored research and the money it provides? Will we not still need research that does not originate in specific social needs, but springs from the inquisitive minds of university professors and students, and is prosecuted simply because it seems intellectually important, and may lead to new perspectives and generalizations, though perhaps not to immediately important, tangible particularities? Is the lone researcher, who likes to choose his own problems, and work at his own pace, perhaps in thoroughly unorthodox fashion, and without an assigned project number or the necessity of periodic reports, likely to lose his independence and support? Will there be room in the universities of the future for a fiddling, philosophizing, rigorously iconoclastic and fiercely independent Einstein, and more humble folk of his kind? Moreover, is the graduate student in danger of becoming a hired hand?

12. My next fear is that if everybody is expected to do research, so to speak, the quality of research will degenerate and that it will become mostly busy work. Now I grant that science and engineering progress by two processes, that of pioneering and that of colonization. We need them both, the adventurous winning of new ground and the systematic consolidation of the new gains. We certainly need the hole-plugging type of research, and most of us are hole pluggers. But I fear that sponsored research tends too much toward hole plugging rather than toward the more imaginative activity of making the holes in the first place. Dare we allow the latter to be flooded out?

13. As an old-fashioned graduate dean I also have fears with respect to the venerable academic requirement of "residence." I am aware, as mentioned earlier, of the values symbolized by the term "diffused university," and realize that, for some students following certain lines of study and research, residence in an industrial or governmental setting may be more valuable than residence in the university community. Nevertheless I feel strongly that for many others this requirement has values we must not lose sight of. There are institutions that give lip service to this requirement and yet deliberately circumvent it by what I would regard as most unworthy devices. Others have succeeded in achieving a consistent point of view and thoroughly defensible practices with respect to off-campus work as distinguished from "residence" work, so called. The situation is in my opinion rather messy. Will the mounting emphasis upon research reduce or increase the dangers here?

14. Graduate departments all over the country are beating the bushes trying to find graduate students and staff in order to meet obligations imposed by research contracts. Are we not in grave danger of losing our sense of values? In a university, opportunities for research should be provided in the main because there are men anxious to do it; there is now a very real tendency that amounts to seeking research contracts first, with all the money they bring with them, and then looking around for the men to do the research. Are there not ominous implications here?

15. Another peril, akin to the one just mentioned, is that faculty members will increasingly be forced to become salesmen or solicitors in behalf of research. The heinous idea is growing that it is the business of a faculty member who "wants to do research" to go out and find the funds, and that one who does not is incompetent, or lazy, and unworthy of support. More and more faculty time

is going into drawing up elaborate proposals for research, then peddling them around in the attempt to get financial support for them, and then into keeping political fences mended so contracts will be renewed at the proper time, etc., etc. There are, of course, some desirable positive values here, as I know from my own experience as project directing professor. In many an institution the situation is under control; but in others it is not. Insofar as practice does conform to this dismal picture, is this not abominable business from the viewpoint of the basic purposes of a university and a graduate school?

Some Assertions

Perhaps now I should quit formulating problems and expressing misgivings, and turn to presenting a definite target for you to shoot at by making a few positive assertions representing my own views.

It is a truism that the key to the solution of all these problems is a first rate faculty. Of course, it requires no originality to say this. There is a question, however, as to just what this means. What qualifications should an engineering faculty have that is to be responsible for conducting graduate work—with all that this implies with respect to research and the various problems I have alluded to? We are by no means all agreed on this.

What I have to say about this is based on the following three assumptions.

First, graduate work differs from undergraduate work, in that its main emphasis is on scholarship in its highest reaches, especially in its dynamic, pioneering aspects. In using the term "scholarship" here I am not trying to distinguish, or draw invidious comparisons, between basic and applied scholarship, or between scholarship and research, between creative art and analytic science. I trust that what I do mean will become clear from the context, and will make sense. Courses or seminars do not truly represent graduate-level work unless they conduct students to the very boundaries of existing knowledge, where they can look out upon the great unknown beyond, become aware of the onslaughts being made upon it, and of the difficulties encountered in the attempt to penetrate into it. Similarly, the research component of graduate work is truly significant for the student only if it offers him the opportunity of active participation in ongoing important research, and of experiencing, himself, directly, the difficulties, successes and failures, the joys and sorrows of it, and of developing a feeling for and understanding of the methodology available, or still unavailable, in his field for grappling with the unknown.

Second, I assume that genuine graduate work provides an intellectual experience in depth—of digging through the surface of immediate problems to the very foundations of one's field, where one is critical of its basic presuppositions, its strengths and weaknesses, and of the rationale of its thought patterns and procedures.

Third, I assume that graduate work at its best provides a broad perspective, revealing how one's own field is related to others, what its great unsolved problems are, in what directions it should go in the future, what its cultural significance is, its professional aspects, the educational values it has to offer, and so on.

To summarize these assumptions, I assume that graduate work in engineering should be an experiential introduction to the intellectual and creative aspects of engineering at its highest levels, and an initiation into the very best of the life and work of the engineering community, including the enterprise of research.

Now this kind of experience can be had, I believe, only in the company of a faculty that has had such experience itself, whose members are themselves first class engineers, *and* scholars, *and* philosophers, *and* educators who know how such experience can be made truly significant for students, and who know what a degree symbolizing such an experience really stands for because they have themselves submitted to the discipline of earning one, and who since earning it have continued to be productive.

We simply must recognize that, as I hinted earlier, true scholarship can be transmitted and research "taught" only by example and contagion. These are severe requirements. But the ideals and requirements of the university have always been high. Moreover, I am talking about the *graduate* faculty of engineering, and here only the very highest standards will do. I believe that one result of the amplification of our research activities will be the increased acceptance of these high standards.

Some Cliches

At this point may I digress to remark about some of the cliches that are abroad today. One is that the need for the Ph.D. is overemphasized and the doctorate has become a union card. One hears that a Ph.D. does not guarantee that a man is a good engineer, or a real scholar, or a good teacher. It is asserted that many a man without a Ph.D. is just as able as one with it. Now obviously there is enough truth in all this that one would not want to deny it categorically. It seems just as obvious, however, that at best it represents only half truths. Since all this has been debated widely, I shall not repeat the arguments. May I merely say that it reminds me of the days when I began teaching—quite some time ago. I began at the high school level. I remember that soon after I got my first job the principal of the school told me that he had had a hard time getting me appointed, because the school board had wanted a more experienced teacher, who had not been to college for more than a year, but who was thought to be as good as any man with a bachelor's or master's degree. In those days many people felt that it was improper to demand a bachelor's degree as a union card for high school teachers. Today we all know there is nothing improper about it and that it makes eminent sense. As a distinguished member of the Penn State engineering faculty recently remarked to me, within ten years everybody will grant that a doctorate is necessary for membership in a graduate engineering faculty. I agree with him, except that I would want to grant, as would he, that there will still be a few—though only a few—great minds towering above the need for a degree, who should be in university faculties.

Another fashionable cliche is: "We want practical men on our faculty—not Ph.D.'s. Ten years in industry yields the equivalent of a doctor's degree." Yet another: "There is too much talk about research. Good teaching is suffering because of our emphasis on research." Again, "There is too much emphasis on publications." To all of which I merely shake my head in wonderment and say: Alas, alas!

Criteria for Student Selection

Here endeth my excursus, and I now return to the main line, and to the consideration of criteria for membership in the graduate student body. Who should be admitted to the graduate school? My answer is, he who strongly desires and can profit from a genuine graduate experience, he who has a passion for knowledge, and for extending its boundaries, who can think critically and deeply and independently, and who "can take" the rigors of the life of scholarship. I am not sure that we have learned how to recognize and select such students. I believe it to be a fact that far too many students with fine undergraduate records turn out to be essentially failures in the graduate school, and surprisingly many with mediocre records turn out to be successes. The difference lies, as I see it, in the spark of originality, the desire to explore the unknown, the penchant for unorthodox thinking—which qualities are usually not evaluated explicitly in the typical undergraduate transcript or entrance examination or even letter of recommendation. Our present tools for the prediction of success in graduate work are sadly inadequate. The really good student must somehow be smelled out. Again this brings us back to the faculty and its competence, for such smelling out can be done well only by a faculty which by virtue of its own predilections and capabilities is sensitive to the particular qualities that are critical for graduate work.

With a really good faculty and student

body we can face the future with confidence. In such a fellowship of professors and students our educational philosophy and practices will not be static, but responsive to the needs of society. It will not live in splendid ivory tower isolation, and yet will recognize the values of communal solidarity. Personal and moral values will not be lost in the impersonal and amoral. The art and the science of engineering will each receive proper recognition. The practical and concrete will achieve balance with the more theoretical and abstract. New fields of study and research, interdisciplinary relations, novel degree programs will not be automatically taboo. In such a community the individual and the team worker will each find his proper niche. Here the values of residence in the academic community will be obvious. Nor will there be occasion for my other lamentations. And finally, in this situation sponsored research will serve and not dominate, and thus will be a truly great blessing.

INTERNATIONAL SYMPOSIUM ON PHOTOELASTICITY

Illinois Institute of Technology has received a grant of $9,950 from the Office of Ordnance Research, U. S. Army, for the purpose of organizing and conducting an International Symposium on Photoelasticity.

Formulation of the proposed program and contract negotiations were made by Dr. M. M. Frocht, IIT professor of mechanics and director of experimental stress analysis, whose research has been sponsored by the OOR for a number of years. The symposium will be held at Illinois Tech on October 29–31, 1961. The only other meeting of this kind was held in Brussels, Belgium, in 1954.

Scientists from the U. S., England, France, Sweden, Switzerland, Germany and Japan are expected to present papers.

According to Frocht, the symposium's chairman, "the program will be comprehensive and will embrace basic aspects, such as two and three dimensional photoelasticity, photoplasticity, dynamic photoelasticity and photothermoelasticity.

"The aim will be to encompass on an international scale the fundamental research activities in these areas, as well as significant technological applications," he said.

Besides IIT and the Army Ordnance Research Office, other cosponsoring organizations are the Society for Experimental Stress Analysis, the Office of Naval Research, the Office of Scientific Research, U. S. Air Force, the applied mechanics division of the American Society of Mechanical Engineers, and the Chicago chapter of the ASME.

The symposium is coordinated with the First International Congress on Experimental Mechanics, which is organized by the Society for Experimental Stress Analysis, and which will be held in New York, N. Y., on November 1–3, 1961.

Impact of Engineering College Research on Graduate Programs and Faculty Development

Viewpoint of a Research Director

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This is one of a series of three papers on the same general topic of "Impact of Engineering College Research on Graduate Programs and Faculty Development." The other two papers have presented the viewpoints of a Dean of Engineering and a Dean of a Graduate School. Thus this paper will be concerned principally with the nature of engineering college research and its relationship to graduate educational programs.

In developing this subject, a group of questions were postulated which were felt to be pertinent to the facts and attitudes concerning engineering college research and graduate programs.

These questions are as follows:

1. What is the present status of research and graduate programs?
2. What are the purposes of research conducted within an engineering college?
3. Is research necessary for the well-being of the college's educational function at the undergraduate and graduate level?
4. What role should students, principally graduate students, play in the research program?
5. What are appropriate sources and means of support for graduate students?
6. What are the proper relationships among teaching staff, research staff and graduate students?
7. How does a college get started in sponsored research programs?
8. What are the relative merits of sponsored and self-supported research programs?
9. What are the real costs of research to an institution?
10. Who should provide "risk capital" to support faculty in new research areas?
11. Can there be too much research?
12. How do we close out research programs after they have served their function?

An attempt is made to answer the above questions in the main body of this paper under the following six sections:

1. Status of Research and Graduate Studies in Engineering Colleges
2. The Scholarly Environment Provided by Research
3. Support of Graduate Programs by Research
4. Institutional and Sponsored Support of Research
5. Research Policies and Practices Affecting Graduate Programs
6. Summary and Conclusions

Status of Research and Graduate Programs in Engineering Colleges

Research programs in engineering colleges have had a long and successful history and certainly could not be thought of as "new." In fact, the first engineering experiment stations were founded just after the turn of the century in 1903–1904, and less formal research programs were common in many colleges of engineering before that time. However, the growth of engineering college research has accelerated markedly since

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the close of World War II when the Office of Naval Research and similar research sponsoring agencies became active in this field. At present the future of engineering college research appears very promising indeed. The magnitude of the current program is indicated by the more than $112,000,000 of research expenditures reported by 118 engineering colleges in the 1959 *Engineering College Research Review*.[1]

Engineering graduate programs also have been in operation in a number of our engineering colleges for many years. It is significant that the increase of engineering graduate degrees conferred has closely paralleled the increase in engineering college research. As an index of this increase in graduate degrees conferred, a study of "Engineering Enrollments and Degrees" published in the 1960 Yearbook of the *Journal of Engineering Education* [2] indicates that of the 154 engineering colleges accredited by the Engineers' Council for Professional Development (ECPD), 134 provide programs leading either to the M.S. or Ph.D. degrees. Of these 134 colleges, 76 offer M.S. programs while 58 offer programs for both M.S. and Ph.D. degrees. As indicated in Table 1, there was a total of 6,562 M.S. degrees and 714 Ph.D. degrees conferred during the academic year 1958–59. Obviously this is a considerable increase over the situation 20 years ago in 1938–39 when 1,219 M.S. and 97 Ph.D. degrees were conferred, or even 10 years ago when 4,783 M.S. and 417 Ph.D. degrees were granted.

The projected needs for engineering faculty to handle the future enrollment increases and the growing demand for engineers with graduate degrees by government and industry would indicate that our present output of engineers with advanced degrees should be more than doubled in the next few years. According to a recent study by the Committee on Development of Engineering Faculties of the ASEE, the needs for new engineering faculty alone will be approximately 1,000 per year during this decade. Due both to the increased complexity of modern technology and to the fact that an ever-increasing number of students must be trained at the graduate level, it will be necessary that a large fraction of new engineering teachers have Ph.D.'s in engineering.

Therefore, in their own best interest, engineering colleges should strengthen and expand their graduate programs and concurrently they should provide appropriate types and amounts of research to support these programs.

TABLE 1

INCREASE IN GRADUATE DEGREES CONFERRED SINCE 1938–39

Academic Year	Master's Degrees	Doctor's Degrees	Total
1938–39	1219	97	1316
1948–49	4783	417	5200
1958–59	6562	714	7276

Scholarly Environment Provided by Research

It is almost axiomatic that graduate studies in engineering must be closely coupled with the research programs of that engineering college. It might be argued that the master's degree program can be conducted without an M.S. thesis, and therefore that research is not necessary to implement such a master's program. It is not the purpose of this paper to argue the merit of an M.S. thesis nor theoretical versus experimental topics. However, it appears to be essential that a basic research program must exist at any institution conducting graduate work whether or not the M.S.-level graduate students actually participate in the research program for credit towards their degrees. To attempt to conduct a graduate program without an appropriate research activity would be akin to operating an educational institution without a library.

Engineering colleges have a responsibility to contribute new knowledge and a better understanding of existing knowl-

[1] *Engineering College Research Review—1959*, published by the Engineering College Research Council of the American Society for Engineering Education, Urbana, Illinois.

[2] Wayne W. Tolliver and Henry H. Armsby, "Engineering Enrollments and Degrees in ECPD-Accredited Institutions," *Journal of Engineering Education*, Vol. 50, No. 6 (February 15, 1960), pp. 450–467.

edge in the areas of engineering sciences which provide the foundations for the engineering profession. Such contributions come about mainly through scholarly activities: study, investigation, search, contemplation—in a word, "research." So that in addition to the normal program of teaching undergraduates and perhaps graduates, the staff must have the stimuli and the productivity of research to fulfill their function as teachers of the future generation of engineers. In the words of President DuBridge of California Institute of Technology,[3] "If the purpose of a university is to advance understanding, then it follows that both the understanding of the student and of the teacher ought to go together. How a man can really teach science or engineering without acquiring a consuming curiosity about the many things that are unknown is beyond me. And how one can get a glimpse of the unknown without an equally consuming desire to tell it to others who will carry it on is also a mystery. An inquiring mind must be the chief possession of university people —and that's the only kind of a mind that can either explore the unknown *or* stimulate students."

The administrative pattern under which research is conducted within a given college of engineering is normally very important to the effective support of scholarly activities and graduate programs. If an institution wishes to develop a strong interplay between graduate instruction and research, the responsibility for and direct conduct of research should be, in my opinion, in the hands of the academic departments. Thus rather than establish a separate special facility and organization for engineering research, such as an "engineering research laboratory," "research institute" or "research foundation," the research could more appropriately be conducted in the laboratories and facilities of the various academic departments under the guidance and control of the regular faculty members of those departments. The head of department, or chairman, then has the direct responsibility for research as well as undergraduate and graduate instruction in that discipline.

Certain types of projects and programs do not lend themselves completely to this mode of operation, and these special considerations may make it desirable to organize and establish these programs outside of the academic departments of the engineering college. Examples are certain exceptionally large programs, classified projects, and certain types of interdisciplinary studies. However, in establishing such special laboratories or organizations, it must be recognized that extraordinary planning must take place and procedures developed which will provide, in fact as well as in theory, the desired close relationship between the research and educational programs. Otherwise, the engineering college and the parent university merely become contractors for the operation of such a special laboratory or organization.

The important point is that if research is to provide a scholarly environment, the regular academic faculty must take an active part in the research program and the nature of the research projects must reflect the interests and capabilities of the academic faculty. Personal experience has shown that effective research cannot be conducted by means of administrative edict and that the most productive research will result from projects which are conceived, proposed and conducted by an enthusiastic faculty.

Support of Graduate Programs by Research

While it is quite logical that engineering college research does serve a major role in the support of graduate programs, it is difficult to find comprehensive data. However, this is a matter of principal interest in this paper. Therefore, attempts were made to obtain the following three types of information:

1. A tabulation of various types of support obtained by graduate students in engineering.
2. A correlation of engineering graduate degrees conferred with engineering college research expenditures.
3. Data on the salary support of graduate students through NSF sponsored research projects.

[3] L. A. DuBridge, "Goals of Research," *Journal of Engineering Education*, Vol. 50, No. 1 (Sepetmber, 1954), pp. 34–39.

TABLE 2

SOURCES OF ENGINEERING GRADUATE STUDENT SUPPORT—FALL 1959

	Students	Per Cent
Fellowships—University Administered	95	12.5%
Tuition Scholarships	29	3.8
Teaching Assistants and Part-time Instructors	152	20.0
Research Assistants and Associates*	241	31.7
Subtotal—Supported by University Administered Funds	(517)	(68.0)
Self-Support, Military, ICA, Foreign National, Etc.	243	32.0
Total Engineering Graduate Enrollment	760	100.0%

* Of these 241 research assistants and associates, 176 or 73.1% are working on graduate thesis.

In regard to item one, it was not possible to find data for other than the writer's own institution without sending out questionnaires. Therefore, the data in Table 2 represent only information concerning the support of graduate students in the College of Engineering at the University of Illinois.

While the data are *not* included in the previous table, it is interesting to note that the Physics Department, which is also a part of the College of Engineering at this institution, has virtually the same distribution of support among its 225 graduate students. It should be pointed out that during the graduate career of any given student he would normally spend one or more semesters of work in research even though on this listing he may be receiving support from other sources. At the particular time (fall 1959) when these data were obtained, 31.7% of the engineering graduate students were employed on research appointments and 73.1% of these were simultaneously registered for thesis research credit toward the M.S. or Ph.D. degrees. Also it should be noted that a number of Fellows were closely associated and often supported, as to expense and equipment, by active research projects related to their thesis research problems. Furthermore, a high percentage of graduate students are employed on research projects during the summer months regardless of the type of support received during the academic year. As has been stated previously, the close relationship between graduate student activity and the research program—particularly regarding thesis research—requires close coordination between the teaching and research functions in given academic areas and also, in part, dictates the type of research which is best suited to the graduate program of engineering colleges.

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TABLE 3

RELATIONSHIP BETWEEN RESEARCH EXPENDITURES AND ENGINEERING GRADUATE DEGREES CONFERRED

Group Designation	Number of Colleges	M.S. Degrees		Ph.D. Degrees		Research Expenditures	
		Total	Ave.	Total	Ave.	Total	Ave.
"A"—more than 10 Ph.D.'s	24	3386	141	594	25	$56,703,000	$2,360,000
"B"—less than 10 Ph.D.'s	32	1715	53	115	4	20,296,000	630,000
"C"—no Ph.D.'s but M.S. degrees	46	948	21	—	—	9,436,000	205,000
Sub-totals A, B, and C	(102)	(6049)	(59)	(707)	(7)	(86,435,000)	(845,000)
"D" not reporting on research	32*	513*	—	5*	—	—	—
Total	134	6562	—	714	—	86,435,000	—

* Of these 32 institutions, 9 reported no degrees in 1958–59, 2 reported 33 M.S. and 5 Ph.D. degrees and research programs but omitted expenditures, the remainder (21) reported M.S. degrees conferred but did not report research through ECRC.

TABLE 4

CORRELATION OF RESEARCH EXPENDITURES AND DEGREES CONFERRED

Group	M.S.	Ph.D.	Research Funds	Annual Expenditures per "Equivalent" M.S. Degree
"A"	3386	594	$56,703,000	$10,900
"B"	1715	115	20,296,000	10,000
"C"	948	—	9,436,000	10,000

engineering college research and support of graduate students was made by reviewing the annual research expenditures reported in the 1959 *Engineering College Research Review* for the various colleges of engineering and correlating these data with the M.S. and Ph.D. degrees conferred by these same institutions during 1958–59 as reported in the 1960 ASEE Yearbook. For convenience in tabulation and to ascertain any effect of the size of graduate programs, the 134 colleges offering graduate studies were divided into 4 categories and comparisons made as shown in Table 3.

Of the three groups which include 102 institutions reporting data on research expenditures and also conferring graduate degrees in 1958–59, Group "A" represents 24 institutions (23.6%) who conferred more than 10 engineering Ph.D.'s during the year. These institutions conferred 55.7% of the 6,049 M.S. degrees and 84.0% of the 707 Ph.D. degrees conferred by the 102 institutions. Also, these institutions reported research expenditures averaging $2,360,000 and totalling $56,703,000 (65.5%) per year during fiscal 1958.

It is of interest to attempt a correlation between research expenditures and graduate degrees conferred by these 102 institutions. Obviously, one would expect to find a different factor for the M.S. degree than for the Ph.D. degree. This is due to the longer period of time required for the Ph.D. with a resulting increased ratio of student enrollments to degrees conferred than is the case with M.S. programs. Also, a Ph.D. program requires more student participation in research than an M.S. program producing the same number of degree candidates. One might arbitrarily assign a factor of 3 to 1 between the Ph.D. and M.S. degrees conferred, i.e., a calculated value of "equivalent M.S. degrees" can be evaluated by multiplying the Ph.D. degrees by 3 and adding this to the number of M.S. degrees conferred. This procedure provides the results in Table 4, which are surprisingly consistent when one considers the extremely wide range of size of institutions and research programs.

Thus, it would appear that an appropriate relationship would be annual research expenditure of $10,000 per M.S. degree conferred and $30,000 per Ph.D. conferred. A check of the individual colleges indicates that a large majority follow this general relationship between research expenditures and graduate degrees conferred. There are, of course, a few individual exceptions which fall on one side or the other of the average value.

A third source of information concerning the support of graduate students through engineering college research programs is a recent paper by Dr. Arthur H. Waynick and other members of the National Science Foundation, Engineering Sciences Program staff published in the December, 1959, issue of the *Journal of Engineering Education*.[4] After a discussion of types of grants, size of grants, and geographical distribution of grants, the paper states: "One of the most important functions of the NSF grants in the Engineering Sciences is the support of predoctoral graduate students working as research assistants." The paper then points out that approximately 35% of total grant funds are utilized for salaries of graduate research assistants. Table 5, taken from this paper, shows these data for fiscal years 1954 through 1958:

[4] Arthur H. Waynick *et al.*, "Support of Basic Research by the Engineering Sciences Program of the National Science Foundation" *Journal of Engineering Education*, Vol. 50, No. 6 (December, 1959), pp. 207–215.

TABLE 5

GRANT FUNDS TO SUPPORT PREDOCTORAL RESEARCH ASSISTANTS

Fiscal Year	Man Years	Dollars	% of Grant	Dollars per Man Year
1954	78.5	$139,770	35.8%	$1781
1955	124.0	244,058	33.7	1970
1956	117.0	254,659	35.1	2175
1957	185.0	422,578	36.7	2285
1958	196.0	468,541	31.4	2390

While there is no direct correlation between these figures and the "annual research expenditure per degree conferred" index just developed, it is interesting to note that the man years listed are "head count," normally on a one-half time basis, and that by doubling the dollars per year to a "full-time equivalent" basis, adjusting to the 100% grant basis, and adjusting for full indirect cost, the cost of supporting a "full-time equivalent" graduate assistant in fiscal 1958 would approximate $17,500 per year. Further, this does not include an estimate of cost to the institution for faculty supervision during the academic year which is normally excluded from NSF grants.

While comparable data are not readily available from other sources, it is an important point that other government agencies, such as the Department of Defense, the National Institutes of Health, and the Atomic Energy Commission, sponsor a considerable amount of research in which one of the prime objectives is the education of engineers at the graduate level toward advanced degrees. Certain industry sponsors of engineering college research also view graduate student research experience as an important factor to their company and their industry.

It is difficult to determine which is "cause" and which is "effect." However, there has continued to be a strong coupling between the number of graduate degrees conferred by engineering colleges and the sponsored research funds from various government and industry sources. Thus, since 1945 there has been a significant increase in research funds for the support of engineering college research and, during this same period, there has been a large increase in graduate degrees conferred in engineering.

Institutional and Sponsored Support of Research

Institutional support of research can be either "material," such as expense and equipment, staff time and use of facilities, or "spiritual," such as encouragement of staff, favorable research policies and procedures, research environment, etc. Both types of support are important and play significant roles in the success of engineering college research and graduate studies.

All forms of support are affected, to a considerable extent, by the actions and attitudes of people responsible for the administration of engineering college educational and research programs, namely, the dean of engineering, the director of research, and the heads of academic departments. However, the eventual success of an engineering college research program depends upon the attitudes and capabilities of the faculty who supervise and conduct the various projects.

The Committee on Research Administration of ECRC has conducted a number of studies and presented numerous reports on various aspects of research support. A general conclusion is that engineering colleges have insufficient funds and other "material" means of support to carry out their obligations. In this connection, it is relatively easy to convince those persons who are responsible for providing university funds of the rising cost of educating large numbers of undergraduate students. However, it is not always so easy to successfully make the point of the true cost of graduate studies and the parallel research program. Nor is it, by any means, obvious to the sponsor of research that his funds will be effectively spent in the more formal aspects of graduate studies closely associated with research programs.

It is standard procedure for institutions to identify and evaluate the "direct" costs attributable to various research programs. However, they often ignore "indirect" costs which are also important items of support. These include admin-

istrative and accounting costs, operation, maintenance and depreciation of buildings and equipment, stenographic and shop services, library costs, etc. The experience of a number of institutions place these indirect costs at from 50 to 75% of the direct salary costs, or from 30 to 50% of the total direct costs. Thus, items of this type represent a substantial contribution to research whether the research is self-supported by the institution or paid from outside sponsor funds. There are numerous circumstances when the institution does not collect "full reimbursement" for indirect costs from research sponsors. This may or may not be appropriate depending upon the particular conditions. However, the institution should recognize that the difference between total direct and indirect costs and that amount being paid by the sponsor represents an out-of-pocket cost to the institution and is a contribution by the institution toward this project. Thus in a material way the sponsor may be dictating the direction of research work which is being supported in part by the institution's own funds. Where this occurs, the institution obviously should be aware of the fact and should compare the advantages gained from this type of expenditure with those that would accrue from equivalent institutional support of other types of research. In all fairness the sponsor should also be aware of such contributions by the institutions and, when appropriate, efforts should be made to obtain "full-reimbursement" for *total* costs of projects.

Sponsored research by its very nature tends to be directed towards the objectives of the sponsor. In some cases these objectives may dictate various types of applied research, routine testing, or product development which are not of particular value to the educational program of the college. The institution must then decide whether it has an obligation or a need to conduct such research or development, or whether the research might be accomplished more appropriately by another type of research organization. One might well consider such projects, for example, to gain experience in a new field or to equip a laboratory with expensive facilities which would be useful for future fundamental research. There is also the factor of "research" as a service which comes under consideration as one of the obligations of publicly supported institutions.

However, in many other cases the sponsor's objectives are best served by the support of research which is basic and fundamental and which is completely compatible with the educational program of the college. Fortunately, this has been particularly true of the programs conducted by certain foundations and those governmental agencies responsible for the support of basic research efforts. Also, there are other government agencies as well as industrial organizations which have missions and interests of a fundamental nature quite compatible with the research goals of engineering colleges.

As previously stated, one of the most valuable "products" from an engineering college research project is the trained graduate student who is himself capable of producing and exploring new ideas. Potential sponsors of research often overlook this positive factor but when it is brought to their attention they are much more agreeable to building flexibility and a fundamental approach into the research under consideration. Thus one can sometimes bring a proposed research program into much closer harmony with the institution's own educational and research objectives.

Research Policies and Practices Affecting Graduate Programs

It may appear to be an egotistical viewpoint of directors of research that the proper administration of research policies and practices has a bearing on graduate programs and faculty development. Yet when one considers the many aspects of research administration that may either set up road blocks or provide smooth highways for the efforts of the faculty and graduate students conducting research, it truly becomes an important ingredient in a successful research program.

In the case of full recovery of indirect costs previously referred to, the policies and practices of the institution may not become too important until the dollar expenditure for research reaches an appreciable fraction of the total institutional

budget. Then the administration must steer an appropriate course between the desires (and misunderstandings) of the faculty project director, the financial needs of the institution, and the attitudes of the sponsor. We all know of instances where the faculty member who is to be project director will conduct informal negotiations with the prospective sponsor. The sponsor states that his organization has a certain amount of money for this project and that the more the researcher's institution takes away for indirect costs the smaller will be the amount available to conduct the research. The faculty member takes this statement to heart and uses every means in his power to keep the indirect cost at the lowest possible figure. What he often does not realize is that by this process, the institution is forced to divert other funds to make up the difference and also, this eventually affects adversely the faculty member and his colleagues in terms of salaries, facilities and services provided by the institution. Also it may well defeat some of the objectives of the sponsor. Ironically, while our ECRC committee on Relations with the Federal Government works hard to establish the principles of full reimbursement for indirect costs, the faculty members who serve on advisory panels of the sponsoring agencies are arguing for inadequate indirect cost rates.

Another area of importance to research administration is finding the means of providing "risk capital" for new faculty members to get started in an effective program of research. Sponsors have a natural tendency to support the experienced faculty member who has an established reputation in the field. Very few sponsoring organizations rush forward to support the newcomer in the field. From the institution's point of view, it is extremely important that such a faculty member be given an opportunity to develop his field of interest. When looked at from a businesslike standpoint, colleges of engineering must provide or find support for research that *might* fail. In the same way that a commercial company must try out new ideas that are not "tried and true," we must take risks—sometimes "long-shots" on new people, new ideas, and new areas of work. In a real sense this is part of the indirect cost of a going research program and such costs, including the considerable expense of developing proposals for new research, must be budgeted as a legitimate cost of doing business. Some types of sponsored contracts provide a percentage of the total contract funds for "exploratory" research. Also certain sponsoring agencies, such as the National Science Foundation, make a concerted effort to support the young, inexperienced staff member. However, many members of research review "panels," who ultimately control the type of research to be supported, do not give proper consideration to this need in our overall national research efforts. As a minimum, the engineering colleges themselves, who have much to gain by the proper development of the neophyte researcher, must provide every encouragement and assistance possible for this purpose. By the same token the faculty member must recognize the situation and be cooperative and content to get along with something less than the *best* during this period of growth.

Another factor of importance in research administration is that of the most effective size of project. Many projects can be most appropriately maintained at relatively low dollar levels and still serve their functions in supporting the graduate program, satisfying the intellectual needs of the faculty member, and maintaining the reputation and leadership of the institution and faculty member in the particular field of research. Projects supported at a level of from $10,000 to $50,000 per year might be thought of as in this category.

However, there are areas of research as well as particular circumstances which make it virtually impossible for some research programs to be conducted under the more usual basis of "the fat professor and his graduate students." For example, there are areas of research that require a scale of operation, including special service functions and especially trained personnel, of the order of $100,000 to $500,000 or more per year. Other activities with inherently large "critical mass" requirements may be closely connected with military security problems or involve basic systems concepts of a sophisticated nature. In many ways, such projects are desirable and appro-

priate for engineering college research efforts. However, there are built-in dangers and difficulties that such projects may defeat the basic purposes of graduate program-oriented research in the college. An alert administration can anticipate many of the problems and provide policies and practices which will avoid loss of effective productivity.

Finally, there is the ever present situation of the faculty member who has "beat" his research topic to "death" and does not recognize the need for a graceful termination (including burial services). Sponsors are sometimes equally guilty of extending research projects far beyond the point of productive output. In many cases the cause of this problem is the isolation of the research project supervisor from the stimulation of undergraduate and graduate teaching. He becomes so concerned with the routine of supervising the project that no time is available for contemplation or the introduction of new ideas. This "treadmill" approach may be much more costly to the institution, in terms of funds, services and facilities, than the expense of initiating a new program which will be much more productive in terms of faculty development and in the support of graduate studies. Drastic and unpleasant measures are often necessary in rectifying such problems unless the administration provides procedures for identifying and eliminating the case before irreparable damage has occurred.

Summary and Conclusions

In summary, this study has developed the following important points:

1. Since 1945 there have been large increases both in engineering graduate degrees conferred and in annual expenditures for engineering college research.

2. During the next few years it will be necessary to more than double both of these activities in our nation's engineering colleges if we are to meet the needs for defense, advance in technology and support of engineering education itself.

3. Research conducted by engineering colleges plays an important role in the creation of a scholarly environment in which inquiry and graduate studies can mutually prosper. It is necessary for the academic faculty to actively engage in research and to provide research leadership.

4. Research programs are an effective and valuable source of support for graduate students, since these programs provide salary through research assistant appointments and also provide for expense, equipment and facility costs related to thesis research.

5. There is an apparent correlation between engineering college research expenditures and the number of graduate engineering degrees conferred by a given institution. An appropriate index of research activity is of the order of $10,000 annual research expenditures per M.S. degree conferred and $30,000 per Ph.D. conferred.

6. There is evidence that many research-sponsoring organizations consider the training of engineers toward advanced degrees as one of the primary objectives of research conducted through their sponsorship. This type of support is well suited to the purposes and needs of institutions of higher learning.

7. Indirect costs are important items in the support of research whether the funds are supplied by an outside sponsor or by the institution. Furthermore, failure to obtain full reimbursement for indirect cost from sponsors may jeopardize the research program supported by the institution.

8. In general, engineering colleges have insufficient institutional funds for the support of graduate program-oriented research. Sponsors with compatible research objectives can effectively supplement these limited funds without destroying the benefits of research for graduate programs and faculty development.

9. Research administrators have the responsibility for developing and administering research policies and procedures which will maintain a close working relationship between the research and educational programs of the institution. They must provide for the support of new faculty in research, the services and facilities necessary for continuing programs, and the graceful termination of projects which have served their purpose. Other functions of the research administrator with such matters as patents, publications, contracts, etc. have not been covered in this paper.

Engineering Guidance

The forward march of our technological progress and economic growth requires the services of ever larger numbers of engineers working in industry, education, government, and private practice. The first step toward increasing the engineering population to meet future needs is to attract additional qualified high school students to the study of engineering. This objective is being carried out by the Guidance Committee of the Engineers' Council for Professional Development (ECPD) through a network of state committees which work directly with the schools.

Each year, thousands of engineers from the ECPD State Committees visit high schools across the country to tell the students about engineering and the aptitudes and preparation required for a career in this field. Through special projects and meetings, vocational counselors, mathematics and science teachers, and parents of high school students are also told about engineering and the career opportunities the profession offers to qualified students. The help of more engineers is needed to further develop and expand the ECPD guidance program.

The ECPD State Committees were organized during the Korean War when the shortage of engineers was reaching critical proportions. There are now committees in all 50 states, the District of Columbia and Canada. The work is coordinated by the ECPD National Guidance Committee through eight Region Chairmen.

Individuals and local groups of engineers have at times undertaken engineering guidance work unaware of the coordinative role exercised by ECPD. This has led to difficulties with school authorities because of duplication in school contacts and uneven standards in the conduct of the work. Engineers interested in guidance are therefore asked to join in the ECPD program, rather than in independent programs, in order that a unified approach to the schools may be maintained.

The ECPD State Committees arouse interest in engineering through a variety of programs which include talks and panel presentations, the showing of films on engineering, inspection trips, promotion of high school engineering clubs and science fairs, television and radio programs, individual counseling, and many other activities. Use is made of National Engineers' Week by many committees as a focal point for special guidance projects. Committees change and modify their programs each year as new ideas are tried out. Guidance is a dynamic operation.

The ECPD National Guidance Committee supports the work of the State Committees through two annual mailings to the nation's 30,000 high schools. The mailings provide the principals and counselors with literature on engineering and include a form which can be used to request guidance assistance from the ECPD State Committees. Information on engineering is also sent to the directors of Summer Institutes sponsored by the National Science Foundation for mathematics and science teachers and by the U. S. Office of Education for counselors. Last summer, 485 institutes having an estimated enrollment of 16,000 teachers and 3,800 counselors were reached in this manner. Each institute director was offered the assistance of the local ECPD Guidance Committee in arranging sessions devoted to engineering. The National Guidance Committee also keeps ECPD guidance pamphlets under review, makes revisions as necessary, and introduces new items for the use of the State Committees.

Further expansion of guidance programs is limited only by the number of engineers interested in participating. Thousands of engineers are already giving unstintingly of their time to this activity. The help of still more engineers is needed. ASEE members who would like to engage in engineering guidance work should first check to see what their Section may already be doing in this

field. Sections may carry out special projects in cooperation with the program of their State ECPD Guidance Committee. Some engineers may prefer to volunteer their services as a speaker directly to the ECPD Chairman for their State. A roster of the State Chairmen is reproduced below:

REGIONAL GUIDANCE COMMITTEES
ENGINEERS' COUNCIL FOR PROFESSIONAL DEVELOPMENT
1960–1961

REGION I

Chairman
R. H. Stockard
Director of Placement
University of Rhode Island
Kingston, R. I.

Connecticut
William H. Austin
William H. Austin & Assoc.
114 S. Main St., Box 343
Cheshire, Conn.

Maine
W. S. Evans
Dean, School of Engrg.
Univ. of Maine
Orono, Me.

Massachusetts
R. T. Bogan
Monsanto Chemical Co.
Springfield 2, Mass.

New Hampshire
Robert N. Faiman
Dean, College of Technology
Univ. of New Hampshire
Durham, N. H.

Rhode Island
John Kowalik
Narragansett Electric Co.
280 Melrose St.
Providence 1, R. I.

Vermont
E. R. McKee
Dean, College of Technology
Univ. of Vermont
Burlington, Vt.

REGION II

Chairman
H. F. Roemmele (Prof.)
Placement Officer & Director of Alumni Relations
The Cooper Union
New York 3, N. Y.

New Jersey
Alfred L. Huber
Jersey City Welding & Machine Works
400 Grand St.
Jersey City, N. J.

New York

Metropolitan
Charles W. Miller
Room 1341-S
4 Irving Place
New York 3, N. Y.

Upstate
E. A. Hilbert
General Electric Co.
General Engrg. Lab.
Bldg. 5, Room 157
Schenectady, N. Y.

REGION III

Chairman
D. M. Seeley
Executive Asst.-Engrg.
U. S. Steel Corp.
525 William Penn Place
Pittsburgh 30, Pa.

Delaware
T. F. Degnan
E. I. duPont deNemours & Co.
Louviers Bldg.
Wilmington 98, Del.

District of Columbia
Joseph H. Broome
Minneapolis Honeywell Regulator Co.
4926 Wisconsin Ave., N. W.
Washington 16, D. C.

Maryland
John B. Gillett
Whitman, Requardt & Assoc.
1304 St. Paul St.
Baltimore 2, Md.

Pennsylvania
George M. Colburn
Engrg. Div.
U. S. Steel Corp.
525 William Penn Place
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REGION IV

Chairman
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Head, Dept. of Mech. Engrg.
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Mississippi
F. H. Kellogg
Dean, School of Engrg.
Univ. of Mississippi
University, Miss.

North Carolina
J. K. Whitfield, (Prof.)
North Carolina State College
Raleigh, N. C.

South Carolina
Harold von N. Flinsch (Dr.)
Head, Dept. of Civil Engrg.

Univ. of South Carolina
Columbia, S. C.

Tennessee

J. M. Henderson (Prof.)
Director, School of Engrg.
Tennessee Polytechnic Inst.
Cookeville, Tenn.

Virginia

Lawrence R. Quarles
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Chairman

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REGION VIII

Chairman

J. G. McGuire
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HELP FOR FRESHMEN AT NYU

New York University's College of Engineering has instituted a tutorial program to help freshmen who are deficient in mathematics or physics. The program is intended to remedy one of the major causes of the high rate of failure among engineering freshmen.

"Poor high school preparation is a long-standing problem," Dr. Robert C. Geldmacher, associate dean of the College at University Heights in the Bronx, said in discussing the new plan. "It is aggravated by the fact that standards in high school science teaching vary from state to state and even from school district to school district."

It has fallen to the colleges to bring their entering students up to par, Dr. Geldmacher said. "If a student is admitted, he is considered to have the personal and intellectual qualifications to pursue a course of study successfully. He should therefore be given every possible encouragement."

Under the NYU program, freshmen are required to take a proficiency test in physics and mathematics, the basic engineering subjects. Those who do poorly are assigned in groups of seven to ten to tutorial sessions that emphasize free questioning and discussion. This year's tutorials are being taught by three deans, a department head, and several senior faculty members.

Beginning this fall, Dean Geldmacher said, the College will offer courses in freshman mathematics on three levels. Entering students who score 75 or better on the proficiency test will take the normal course. Those who score between 50 and 75 will be advised to take an enriched course that will meet an extra hour per week. Those scoring under 50 will take a special three-semester training sequence.

Next fall, Dean Geldmacher said, an advanced course will be added for outstanding freshmen.

Report on Engineering Design

In the last decades, an enormous increase in the number and complexity of problems facing engineers has resulted in a corresponding increase in the number and complexity of mathematical techniques which are used by engineers and taught in engineering schools.

The result has been that engineering curricula have been crowded to the point where it is now patently impossible to put more than a fraction of this material into a course of study of any reasonable length.

Two aspects of this change have been increase in the mathematical content of engineering subjects and displacement of subjects centered around devices by subjects centered around physical principles and mathematical techniques. Thus the study of engineering analysis is being expanded at the expense of subjects entitled "design" and involving synthesis.

It seemed to many faculty members that whether this trend was desirable or not, it was wise to study it, to see where it was leading and to determine if it provided new educational opportunities.

At the suggestion of the Committee on Engineering Curriculum, Dean Soderberg, with the knowledge and approval of Dean-designate Brown, appointed this committee to study engineering design with the following charge:

(1). To arrive at a common understanding of the meaning of words relating to design.

(2). To find what elements are common in the process of design in various engineering fields.

(3). To study the problems of the practicing designer.

(4). To study analytical techniques adapted to solution of the designer's problems.

(5). To consider the problem of teaching design in the M.I.T. School of Engineering.

The committee was encouraged to interpret the word "design" broadly. This was indeed fortunate because the committee found itself in the middle of a larger problem. What should the formal part of engineering education attempt to teach? What balance should be maintained between teaching the scientific principles, the analytical tools of the trade, the state of the art, and teaching engineering attitudes?

The committee met during August and September for 4 weeks. The first week was occupied primarily in a study of the semantics relating to the problem, with some attention to special design tools.

The second and third weeks were devoted to meeting with practicing engineers, in order to discuss what they did, what their problems were, and what methods they used in the solution of these problems. Late in each day the subject of engineering education was introduced, and the guests were invited to comment.

Practicing engineers representing the following engineering fields attended:

Airplane Design
Machine Tool Design
Design of Bridges, Tunnels and Airports
Design of Diesel Engines and Gas Turbines

An interim report made November 3, 1959, to the Dean of Engineering, Massachusetts Institute of Technology, based on a study carried out at the Cambridge School, Weston, Massachusetts, between August 24 and September 18, 1959. This study was made possible by funds granted by the Carnegie Corporation of New York. That Corporation is not, however, the author, owner, publisher, or proprietor of this publication, and is not to be understood as approving by virtue of its grant any of the statements made or views expressed herein.

Design of Electrical Machinery
Operations Research
Design of Electronics Systems
Design of Nuclear Submarines
Design of Chemical Plants
Design of Communications Systems

Aside from the desire to have a wide variety of fields represented, the sole criterion for the selection of guests was outstanding engineering accomplishment coupled with ability to communicate. Engineers came from the East, the Middle West and the West Coast. One came from England.

The committee also had the advice and counsel of several additional faculty members and industrial leaders.

The final week of the committee was spent in summing up our experiences, drawing conclusions, and formulating recommendations.

Semantics

The first problem tackled by the committee was to establish communication between its members by agreeing on a common language.

One of the primary difficulties experienced in any effort of this kind is the tendency of every human being to use words as weapons to advance his own status and position rather than to reveal and clarify a thought. Through this process words come to assume meaning and carry emotional content quite apart from their dictionary definitions. Certain words become "good" and lose usefulness because their emotional content prevents an accurate evaluation of the nature of the referent. As an example, during the study, many people stated that we should teach "fundamentals," but attempts to find an accurate description of the referent led nowhere. Where does the foundation stop and the superstructure begin? Do the words *fundamental* and *applied* define mutually exclusive categories? Is Newton's law fundamental? Is it applied when it refers to a heavenly body? Or is it applied only when it is used in the analysis of a machine?

"Bad" words are useful chiefly as missiles to be guided to the enemy.

The Study Committee compiled a list of words which, in educational circles at least, had acquired emotional content and thereby had lost a part of their usefulness. The words below are a sample.

basic	applied
broad	specialized
creative	routine
education	training
fundamental	descriptive
professional	vocational
quantitative	qualitative
scientific	intuitive
theoretical	practical

In many cases emotional response is best evoked by a juxtaposition of words in the right- and left-hand columns; for example, there seems nothing wrong with being "practical" unless it is contrasted with being "scientific" or "theoretical." We cannot communicate without being "descriptive" but how much better it is to be "fundamental!"

An attempt, at least, has been made in this report to avoid summoning the emotions in support of the argument.

A considerable semantic difficulty is offered by the failure of the general public to distinguish between science and engineering; in fact the tendency of the public is to use the word *science* when *engineering* would more accurately specify the intended referent. Simply stated, science implies a body of knowledge and a scientist is one who professes to a part of this knowledge. The scientist is primarily concerned with discovering, codifying and understanding the nature of the physical world, of searching out similarities, of making generalizations by means of which natural phenomena may be predicted. He seeks to solve problems which have definite answers. His output is primarily information.

The goal of the engineer is to utilize knowledge of the physical world for social benefit. In order to achieve this end he designs and builds physical objects: devices, structures, processes and systems. The problems which he seeks to solve have many possible answers from which he must select an appropriate solution.

The scientist's problem is to discover truth, the engineer's to determine a course of action.

After considerable discussion the com-

mittee came up with the following definition:

"Engineering design is the process of applying the various techniques and scientific principles for the purpose of defining a device, a process or a system in sufficient detail to permit its physical realization."

It was agreed that the word *design* includes the entire decision-making area. What electrical engineers call *systems engineering* is included as well as what chemical engineers call *process design*. It also includes the area which electrical engineers call *design*. This latter area seems little different from what others call *handbook engineering*. The use of a "bad" word here is intentional since it accurately conveys both the meaning and the emotional response.

Design may be simple or enormously complex, easy or difficult, mathematical or non-mathematical; it may involve a trivial problem or one of great importance.

A design problem implies action and a final result which has physical reality, not a result which is only an idea or a report. Characteristic of the design problem is that there is no unique solution; in fact to ask for the "correct" answer to a design problem is to ask a meaningless question. There is no *correct* answer. There are usually several adequate answers, some of which may be identified as "better" than others. The formulation of most design problems is incomplete and the designer must himself define the problem. The data available for a design process are almost always incomplete, and contain much irrelevant matter. Very often the data are redundant and even contradictory. The designer must use judgment in the selection of data and in deciding when the available information is sufficient for accomplishing the task in hand.

Design is a conceptual process, one in which at least a fragment of a mental plan is necessary before the process can proceed. It is often an iterative process in which each decision must be tested by examining its effect on sub-problems. A designer with the ability to see many moves ahead can progress rapidly. Design often involves several different disciplines; for example, fluid mechanics and strength of materials, or dynamics and electric circuit theory. The skill of the designer is measured by his ability to identify limits and to make appropriate compromises.

Accepting this definition of design, we may ask the question, what engineering activities other than design are there? Such areas as manufacturing, operation, or experimental research are not *per se* design, although work in any of these areas often involves design. On the other hand, manufacturing, operation and experiment are matters of concern to the designer since they constitute boundaries of the region within which he must operate. The modern tendency to specialization throws up barriers which cause particular difficulty in the design area.

If we add the area the designer must be knowledgeable about to the area he must operate in, we see that it includes nearly if not all of what is called engineering. He must indeed be a broadly trained man whether he received that training in school or after graduation.

Specialists can aspire to design either by broadening their knowledge or limiting themselves to design problems in which their specialty is of paramount importance. Specialists will normally be confined to a portion of the design activity.

Also, it appears that this Committee on Engineering Design would broaden its scope only slightly if it dropped the noun *design* and became the Committee on Engineering.

Languages of Design

One source of confusion in thinking about design is the tendency to identify design with one of its languages, drawing. This fallacy is similar to the confusion which would result if musical composition were to be identified with the writing of notes on a staff of five lines. Design, like musical composition, is done essentially in the mind, and the making of drawings or writing of notes is a recording process. The designer, however, uses drawing for self-communication just as everyone uses words for thinking. This use of drawing as an extension of

the mind, a sort of external (and reliable) memory can be a very important part of the design process. Drawing should be taught not primarily to give the student facility in the use of tools—pencil, triangle, tee square, and most important, the eraser—but to give him practice in pictorial extension of the mind. It is not to be expected that all students are equally endowed with the ability to think pictorially any more than to think mathematically. Somehow educators tend to look upon mathematical ability as a more desirable quality than the ability to think in terms of spacial relations. Before dismissing the latter as something of lesser merit, it may be well to reflect that one of the great engineers of all time, Leonardo da Vinci, was essentially a draftsman, not a mathematician.

Pictorial language is especially well adapted to expressing particular physical form and physical space relationships. Functional relationships are often better expressed by a symbolic language. Such languages have particular facility in expressing generalizations without specifying detail. The chemical engineer uses the flow sheet, the electrical engineer the circuit diagram, and all kinds of engineers use the block diagram as important tools in the conceptual process.

The designer often uses the symbolic languages of mathematics but usually in connection with the analysis of a design rather than directly in the conceptual process.

The particular language the designer uses depends upon the problem at hand and the training of the people involved. In any case, it may be stated that the design process is going on while the designer is talking to himself. When the plan is completely formulated the design process is essentially complete. Thus a draftsman who is merely trying to communicate to others an already formulated plan is not designing. A designer often draws to help him formulate a plan.

Engineering in Industry

The guests, from whom the committee received a picture of engineering in industry, represented organizations ranging from an essentially one-man consulting firm to a large research and development laboratory. Committee members themselves were able to contribute to this picture from their own industrial experience. A wide range of design problems was covered.

In all of the design problems use was made of:

logic,
physical principles,
experience, judgment, and intuition,
numerical computation,
drawing, symbolic diagrams,
experiment;

but these ingredients were mixed in widely varying proportions.

Other differences appeared; for example, the extreme importance of the development process in such an item as an inertial navigation system may be contrasted with the entire absence of the development process in building a bridge or a tunnel. Here it is clear that the impossibility of building a prototype controls the nature of the design process.

The following quotation from one of our guests, Mr. C. H. Elmendorf of the Bell Laboratories, gives some idea of the diversity encountered in design problems:

"The methods used in balancing, integrating and optimizing the hundreds of parameters and design choices involved in a major system are so dependent on the detailed situation that broad tutorial generalities invariably turn out to be trite or meaningless. The type of system; the background and capabilities of the people involved in the program; the state of the required knowledge; the demands and attitudes of management and customers; the capabilities of supporting organizations; schedules; available funds; and a host of other factors all bear on methods of organizing the work program and of reaching the necessary judgments and decisions."

New design problems refuse to fit any pat program for their solution. The consequent need for a fresh attack for each constitutes the challenge of design.

In spite of the diversity of problems and organizations, the Committee found a remarkable uniformity of opinion among our visitors on subjects relating to engineering education.

One area of agreement was that each guest was essentially satisfied with his own educational experience even though these differed widely among the group. When coupled with the fact that all guests were eminently successful engineers, this observation does not seem too surprising.

A number of guests dwelt on the desirability of an engineer's having a good grounding in "fundamentals." The word *fundamentals* was not precisely defined, but in all cases it included basic physical principles. In some cases it appeared to include the application of these principles and in some it included quantitative mathematical techniques.

Recent engineering graduates were criticized for unwillingness and inability to consider a complete problem such as a design problem. Instead they showed a desire to seek a fully specified problem which could be answered by analytical methods. It was stated that engineers with advanced degrees were even more prone to avoid a complete problem. When they did tackle a whole problem, they tended to struggle to analyse it with all generality rather than to break it down into manageable pieces. Men trained at second-rate schools were often found to be more willing to attempt the solution of a whole problem than those trained at first-class schools. In spite of inferior technical education these men often worked into positions of leadership whence they directed the work of those from the "better" schools.

The tendency of the young engineer to look upon himself as a specialist and to balk at tackling jobs outside of his specialty was noted. This tendency was also said to be more prevalent in the case of men with advanced degrees.

In short, young engineers feel at home in solving problems which have numerical answers—the kind of problem used in school for teaching analytical techniques. They fail to respond to the stimulus of the more complex problems of a real situation. Several times it was remarked that young engineers tend to consider problems which do not involve mathematics at least at the level of the calculus as beneath their dignity—something to be turned over to a technician who was without the benefit of higher education. This attitude often prevails in spite of the clear indication that the most important decisions in a design problem must often be made without assistance from higher mathematics.

Another interesting area of agreement concerned the manifest effectiveness of engineers who had had the benefit of an internship in one of the academic or peripheral laboratories where problems similar to those in industry are found, and where, early in his career, a man is given a measure of responsibility under the close supervision of experienced and sympathetic engineers.

It was also brought out that while night schools and other aids to learning analytical subjects on the job are quite generally available, opportunities for the internship kind of training are rare in industry or in government laboratories. Further, as one of our guests stated, "It is much easier for a graduate engineer to obtain the details of a new analytical technique from the literature than for him to reorient his attitude toward a technical problem."

Have we indeed, as one guest suggested, "gone overboard on the analytical approach"?

Use of Analysis by Designers

In a design problem, synthesis must come first. It is necessary to have a concept before it can be analysed. Furthermore, nearly every physical device is far too complex to permit analysis directly. In order to make the problem amenable to analysis, it is necessary to conceive a model having the essential characteristics of the actual device, but simplified to eliminate nonessential detail. A physical device always differs from its model, and judgment is required to select a proper model, or to decide whether a useful model is indeed possible. The use of automatic computation is making it possible to use more complicated models, but it should not be assumed without proof that a more complicated model better represents the physical device. In short, numerical analysis must be used with judgment.

The false assurance which engineers, and more importantly management, often derive from an over-analysed problem can have disastrous results.

Perhaps the most important use of analysis by the designer comes from his knowledge of general principles and the *form* of mathematical relationships rather than from actual computation. This knowledge gives limits and direction to the conceptual process.

The good designer avoids the trap of purely qualitative thinking. He makes many rough estimates to establish the importance of various factors. Often he investigates limiting cases by the use of extremely simplified models. In many cases the answers so obtained are sufficient to his purposes and more complex analysis is unwarranted.

Good designers recognize the assurance that comes with numerical computation and they therefore strive to increase its application when it will result in more reliable decisions. As a result, the design process tends to become stereotyped or programmed as a problem becomes older and a larger proportion of decisions can be made on the basis of numerical computation. This is not to say that an ingenious man will not be able to make a valuable contribution to an old field. This phenomenon has happened many times.

The designing engineer who remains on the frontiers of engineering finds himself making only a small fraction of his decisions on the basis of numerical analysis. When the problem becomes older and more decisions are based on numbers, he moves on to a new and more difficult field where he again finds that a small fraction of his decisions are based on the kind of analysis taught in engineering schools. This is not said to try to belittle the importance of analysis. Everyone recognizes it as an essential tool of the trained engineer. It does not, however, answer all or even a majority of the questions an engineer must answer in a typical design problem, particularly a new one. It seems unlikely that numerical analysis will ever answer more than a small proportion of these questions. The remainder of the questions must be decided on the basis of *ad hoc* experiment, experience (the art of applying knowledge gained by former experiments on the same or similar problems), logical reasoning and personal preference. The subconscious reasoning process based on experience, which we call intuition, can play a large part.

It is usually a shock to students entering practice to discover what a small percentage of the decisions made by a designer are made on the basis of the kind of calculation he has spent so much time learning in school.

Engineering Education

The ostensible content of an engineering education is a body of knowledge and a set of skills which should enable a student to solve engineering problems. It is clear that education is much more than this. Whether consciously taught or not, students acquire attitudes and habits as well as information and techniques. The results of this study suggest that we have been paying far too little attention to the attitudes we instill in our students. Certain specific attitudes are required to make effective engineers, and engineering schools cannot escape the responsibility for the attitudes as well as the knowledge and skill of their students.

Important among these attitudes are:

(1). Willingness to proceed in the face of incomplete and often contradictory data and incomplete knowledge of the problem.

(2). Recognition of the necessity of developing and using engineering judgment.

(3). Questioning attitude toward every piece of information, every specification, every method, every result.

(4). Recognition of experiment as the ultimate arbiter.

(5). Willingness to assume final responsibility for a useful result.

It is essential to inquire whether these attitudes are fostered by the kind of education we provide and to study the effect of the changing educational pattern in this respect. We cannot dismiss the subject as something outside the province

of higher education, since attitudes are slowly acquired, difficult to change and best instilled at a relatively early age.

Fundamental physics, chemistry and mathematics as taught to engineers, together with engineering science subjects such as applied mechanics, electric circuit theory, thermodynamics, etc. have a common characteristic. Questions asked of students are overwhelmingly what will be called single-answer problems. This classification includes all problems which can be answered with numbers or functional relationships; in fact it includes all problems which have answers which can be generally agreed upon. Reasons for the popularity of this type of problem are not hard to find. Single-answer problems provide an essentially objective standard against which the performance of the student can be measured. Such problems are essentially closed-ended. When the answer has been obtained the problem is solved and there is no need to bother with it further. The student can be taught a series of logical steps to arrive at the answer. The teacher can measure his own effectiveness by noting the percentage of his students who arrive at the right answer when tested. Because of the existence of an objective standard, people inexperienced in engineering, graduate students for example, can be, and often are, entrusted with teaching.

Examination of the effect of the single-answer problem on engineering attitudes reveals:

(1). Incomplete or contradictory data have little place in single-answer problems.

(2). Engineering judgment is not required of either the student or the instructor, hardly a situation to encourage its development.

(3). The very existence of an objective standard puts the instructor in an almost impregnable position, which only a few of the very bright students will dare to challenge. Skepticism and the questioning attitude are not encouraged by this situation. Neither the data, the applicability of the method, nor the result are open to question.

(4). The single-answer problem usually suggests the infallibility of logic rather than the ultimate word of experiment. The early history of science bears witness to the paralysing effect of this attitude.

It seems clear that the single-answer question has a rather strong negative effect on attitudes we hope to teach our students.

The faculty itself is very conscious of this problem. How many times have you heard the following complaint?

"When I give my students an open-book quiz, they read the question, shuffle frantically through their books and notes in search of 'the formula,' substitute the given data, and crank out an 'answer.'" Clearly the complaint is directed to the attitude of students who have been taught to solve many single-answer problems.

The words of Dr. E. H. Land taken from his ninth Arthur Dehon Little Lecture seem particularly appropriate to this point.

". . . Where anywhere in life is a person given this curious sequence of prepared talks and prepared questions, questions to which the answers are already known? . . . Where again is the structure of authoritarianism masked by the genuine friendliness of the democratic people who are his leaders?

". . . The role of science is to be systematic, to be accurate, to be orderly but it certainly is not to imply that the aggregated, successful hypotheses of the past have the kind of truth that goes into a number system."

Recognizing the shortcomings of the single-answer question, what alternatives have we? How can we involve our students in situations which plant the seeds of engineering judgment, reward a questioning attitude, force decisions in the face of incomplete data? What sacrifices in content must be made to bring our educational scheme into balance? Will this involve great expense? Shall we have two essentially different approaches, one to make "analyzers" and one for "utilizers"? How shall we differentiate these two? These are samples of the

questions which were raised by this study.

Thinking along these lines has been going on in various places on the M.I.T. campus for some years, and action has resulted in some areas. Your committee has borrowed freely from these sources.

Two cases of individual thinking and action are given below. Both are examples of what can be done in engineering science subjects. Clearly, similar approaches can be used in other subjects.

Comprehensive Problems

The first of these will be called the analytical experiment. It is well illustrated by a problem devised by Prof. McClintock which is stated in full in Appendix A of this report. This problem is deceptive since it appears to be just another single-answer question. However, the essence of the problem is making an appropriate conceptual model of a physical situation and *checking this model by experiment.* Finding "the answer" is secondary to the purpose of developing judgment regarding the validity and accuracy of analysis. The problem leads naturally into discussion of how to generalize the result, it raises more questions than it answers, it is open-ended. Furthermore it emphasizes the necessity for an experimental foundation.

The second type of problem is illustrated by one conceived by Prof. Sherwood. This problem is given in Appendix B. The statement of this problem calls for a useful result and it is thus essentially a design problem. The data are carefully chosen to lead not to a single answer, but to a situation in which many solutions are possible. As a result, imagination and engineering judgment are valuable aids in solving the problem. The problem leads to a search for additional needed information concerning pipelines, heat exchangers, etc. Since it has many solutions, it encourages a questioning attitude. Like the previous problem it suggests avenues for further study.

Problems of either of these types offer great educational advantages but either type consumes a great deal of time. Your committee firmly believes that efforts should be made to increase the use of problems of these types even at the sacrifice in coverage. In most engineering science subjects there are adequate texts available and complete coverage of a subject in lectures may be unnecessary, even undesirable.

The extensive use of comprehensive problems would provide considerable improvement in our engineering education. Your committee does not believe, however, that this would be enough to bring our education into balance. Several other lines of attack on the problem are necessary.

The Engineering Faculty

Inventing, developing and presenting problems such as these require ingenuity, time and engineering experience. The size of the class must be small enough to encourage student participation. It is not to be expected that classes can be handled by inexperienced people. The question of finding experienced teachers leads to problems of hiring, of promotion, and of providing further engineering experience for staff members. All of these factors are likely to increase the budget for teaching salaries. It seems trite but perhaps necessary to say that embryo engineers should be taught by engineers.

The policy of recruiting our faculty primarily from newly made Ph.D.'s and Sc.D.'s leads to teaching analytical techniques to embryo analytical technicians. There are at least two ways to ameliorate this problem: (1) hire a percentage of experienced engineers; (2) see that staff members have opportunity for engineering experience.

The first problem obviously involves the differential between teaching salaries and industrial salaries, a differential which in the case of engineers can be largely offset by consulting, but which plays a part in the difficulty of hiring. More importantly, since the doctorate seems now to be considered essential for a teacher, the number of qualified people with industrial experience *and doctorates* is small. It is evident that emphasis on the advanced degree as a qualification is not without its drawbacks. The same

can be said about the relationship of learned publications and promotions. The man with industrial experience is far less likely to have an imposing list of publications and may find himself at a real or imagined disadvantage vis-a-vis his colleagues. The matter of making an M.I.T. faculty position more attractive to engineers with outstanding records of accomplishment other than degrees and learned publications could well be studied.

The problem of encouraging staff members to acquire engineering experience is perhaps not as difficult. Many of our younger faculty members have taken leaves of absence to spend a year in an industrial atmosphere. If the job is well selected, a year in industry can be a valuable experience. Particular pains must be taken to insure that the faculty member is used as an engineer and not as a computing device. Your committee rejects the argument that if people leave teaching they are likely to stay in industry at high salaries. M.I.T. must retain its position to compete in the open market for these men. We must find means of encouraging faculty to go out and return.

Summer employment is another possibility which is now widely available to staff members. Your committee feels that summer jobs are helpful but not a substitute for a longer period of industrial employment.

Valuable engineering experience is also available to staff members who have the opportunity of working in those M.I.T. and peripheral laboratories where complete engineering problems are attacked.

The Importance of Experiment

It seems trite to remark that all of our science and engineering rests on a foundation of experiment. Thus when we speak of the "fundamentals" of an engineering education we should certainly include the experimental method, by which we must test every hypothesis and every analysis.

The competent engineer appreciates the power of the experimental method. He understands the interplay between experiment and analysis which is typical of engineering solutions, and he uses experiment and analysis as the situation requires. The value of Prof. McClintock's problem arises primarily from the opportunity to compare analysis with experiment. In order to counterbalance our preoccupation with analysis, enthusiasm for experiment should be evident in all areas and at all levels of the educational process. Students should consider it entirely natural to use experiment to study a point or to settle an argument arising in the classroom. In some areas, notably electronics where "breadboarding" is relatively easy, the ideal described above has been approached. In others, enthusiasm for the experimental method is conspicuously lacking.

Experimental research sponsored by government and industry contributes greatly to the education of graduate students. However, the pressure to produce results for the sponsor prevents any considerable involvement of undergraduates.

We must endeavor to see that the experimental method is an important part of the students' life during their undergraduate years. This is not so much a matter of new laboratory subjects as new emphasis, especially in engineering science subjects, on the experimental method. For example, it should be entirely appropriate to assign problems requiring experimental solutions. New laboratories, adequately staffed, flexibly equipped and freely available to staff and students alike will be required for this purpose.

Internship

The extraordinary success of the internship procedure with graduate students suggests the desirability of its use in earlier years. Part of the success of men who go through the internship procedure in one of the M.I.T. or satellite laboratories where engineering problems are attacked is undoubtedly due to the fact that they are a carefully selected group. It also seems clear that they profit greatly from the experience.

How can we give this kind of experience to undergraduates? This question is not easy to answer. Graduate students

in internship are expected to be able to take responsibility and to contribute substantially to the research program. They spend a large fraction of their time on their projects, accepting slower progress toward their degree. They are paid salaries from sponsored projects which must produce useful results. Such projects cannot be expected to support students who do not contribute to these results. It is clear that some undergraduate students could participate in these programs under similar circumstances. In order to involve more than a very small number of students, it would necessary to provide more staff supervision than is now available. It is unreasonable to expect that funds for this purpose should be taken from sponsored projects.

Primary reasons for the success of internship are:

(1) The atmosphere of the laboratory is generated by the necessity of solving real problems.

(2) Laboratory directors and project leaders can choose which students and how many they desire to aid in their researches.

Any scheme to involve undergraduates must preserve these conditions.

While a laboratory program contrived for the purpose of teaching can be a valuable aid to education it is not to be expected that it can take the place of a real internship experience.

The cooperative scheme is another way of giving an internship experience. The chief difficulty with this arrangement is that of monitoring the students and the cooperating organizations in order to see that the students are given a proper variety of jobs and are receiving sufficient attention. These difficulties are minimized in the practice school scheme where a faculty member with responsibility for the program is maintained in residence. Under this arrangement the students are not paid to work for the cooperating organization and their is thus no division of obligation between education and output. Your committee feels that the sort of endeavor represented by the practice school is useful and important; we hope to see it extended.

Design Experience

In addition to the foregoing suggestions for improving our engineering education, it seems essential to involve students, preferably starting early in their educational careers, in the decision-making process we call design.

The ideal goal of education in the design area is a problem carried through construction, test and evaluation. The invaluable feedback of information from actual test can be provided only by completing the job. In some areas of engineering this ideal can be quite closely approached; in others, it is a difficult goal indeed.

While the goal is clear, it is no more realistic to require that a student's first design experience be complete than to insist that his first experimental experience be a research job or that his first mathematical experience be an unsolved original problem. As in other areas, it is well to approach design by easy stages. The recent experiments of the Civil Engineering Department indicate one way of handling this problem.

As already indicated, design covers such a diversity of problems that it can best be taught by the case method, that is, by designing something. What this something is, must depend upon the knowledge and experience of the instructor. On the other hand, student motivation should also have an influence on the field from which the design problem is chosen. This, together with the fact that only a small number of students can be handled simultaneously by a teacher of design, suggests that students and teachers be matched according to their interests.

It has already been stated that design can be taught only by experienced designers, whose experience has been in the field in which they teach. Perhaps here more than anywhere else is the greatest difficulty of assembling and maintaining a competent teaching staff. Competent designers are valuable and highly paid engineers, particularly if they also have the analytical facility which is essential to a faculty member in an engineering school. This problem, although difficult, seems to have been

solved in our School of Architecture. Your committee has two specific recommendations along this line. One, to encourage faculty members to work on complete engineering problems in academic and peripheral laboratories which handle such problems, and by taking periodic leaves of absence to work in industry. The second concerns the provision of endowed chairs for the purpose of bringing qualified engineering designers from industry for limited periods for the purpose of teaching design in their special fields. This two-way street should also help to keep industry and educational institutions aware of their mutual problems and responsibilities.

One Path or Two?

Your committee recognizes that design ability and analytical ability do not always occur in an individual in equal proportions. Some students are intrigued by the mathematical problems of analysis; others find challenge in the concepttual and decision-making processes of design.

Should we recognize two different types of students and provide two avenues leading to different kinds of occupations?

First, your committee believes that all students should have some exposure to both types of activity. For all students, we recommend that they be involved in more conceptual and decision-making activity than now exists in their program. This experience should start early.

Second, provision should be made for students who show particular aptitude for design to spend more time in this area. This immediately brings up the process by which students select the area in which they wish to work. The analytical part of an engineering education now seems to be considered the most difficult, most challenging part, while the remainder of engineering is considered to be an exercise of a lower order, conducted in a physical region located nearer the seat of the pants than the brain. If we persist in this attitude, it is clear that the students who wish to emphasize design will be selected from those who do poorly in analysis. Under these circumstances, it is extremely doubtful if it is worth the trouble to provide special attention for those students.

On the other hand, if we can recognize the challenge of design as potentially equal to that of any analytical subject, it will be very well worth the effort to encourage rigorous design activity. Then and only then will it be possible to select students for design because they have a talent for it and not because they have inadequate talent for analysis. By rigorous activity we mean one demanding a high order of conceptual effort. Design must not be allowed to become a refuge for second-rate students.

If we are to have two paths, it is essential that the design experience start as early as possible so that students will have the opportunity to sample the conceptual, decision-making kind of subject to compare with the familiar analytical subjects, and to give *some* basis, admittedly incomplete, for making a decision.

Your committee believes that, as a goal, every M.I.T. student intending to go into either science or engineering should, in his freshman year, be exposed to a conceptual, decision-making subject. For this purpose, we visualize a single subject, involving many engineering departments rather than a variety of subjects each covering a single field. We recognize that planning and carrying out such an activity is a major project which will take a great deal of time and effort.

Specific Recommendations

We recommend

(1) That all students be involved in the design process beginning with the freshman year. Until a suitable arrangement can be made, we recommend that
- (a) An interdepartmental freshman elective in design be provided.
- (b) The present scheme of voluntary work of freshmen in existing laboratories be recognized and accorded academic credit.

(2) That engineering subjects be examined with a view to increasing the number of problems involving decision-making and experiment.

(3) That all types of engineering internship be encouraged and recognized with academic credit where appropriate.

(4) That flexibly equipped laboratories provided with adequate academic and technical supporting staff be made freely available to faculty, undergraduate and graduate students alike.

(5) That chairs of engineering design be established for the purpose of attracting experienced designers from industry for limited periods.

(6) That the recommendation of the Committee on Engineering Education, ". . . A regular program of sabbatical leaves to increase the *scholarly* attainment of the faculty" be broadened to provide the same opportunity for sharpening and focusing the *engineering* attainments of the faculty.

Respectfully submitted,
Committee on Engineering Design

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O. C. KOPPEN
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APPENDIX A

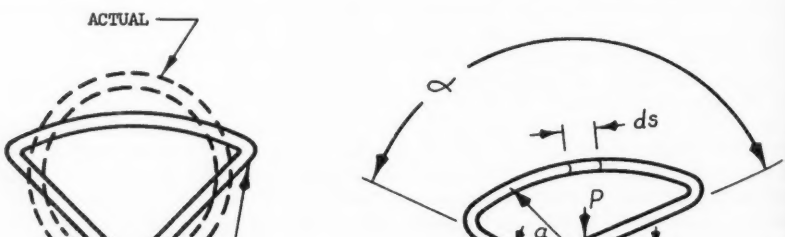
A Problem in Introductory Elasticity

PROF. F. A. McCLINTOCK

Toward the end of the sophomore subject in Introductory Elasticity, where the bending and twisting of beams are considered, an 11/16 I.D., 1 1/16 O.D. spring lock washer was passed around the class on a number of occasions with the request that its stiffness be estimated. The stiffness was later to be determined experimentally by squeezing the washer between hard plates in a compression testing machine.

At first the students simply guessed the stiffness, giving values from 700 to 8,000 pounds per inch. It is interesting to note that a similar range was obtained in an informal poll of staff members.

A second estimate of the stiffness of the washer was obtained by posing the problem stated below in a quiz, in which the shape of the washer was idealized so that its elements were in either pure bending or pure tension. With this



Evaluate $\frac{dP}{dw}$ for $d = .16$ in., $a = 90°$, $a + 0.75$ in.,

Young's Modulus, $E = 30 \times 10$ psi, Poisson s

Ratio, $\nu = .3$.

idealization the stiffness was calculated to be 920 pounds per inch.

Quiz Problem

Estimate the slope of the force-deflection curve for a spring lock washer according to the idealization shown in the sketch. Note that in the curved part of the washer the angle of twist per unit length $d\Phi/ds$, acting along the element of length ds, contributes an amount $[a(d\Phi/ds)ds]$ to the relative deflection between the ends.

The instructor made a so-called exact solution taking into account combined bending and torsion and also the rectangular cross section of the washer. This led to an estimate of 1,220 lbs. per in. Revision of the estimate for the fact that the load was applied at the inner radius rather than the mean radius of the cross section resulted in a value of 1,500 lbs. per in., so the instructor estimated a value of 1,300 ± 15% lb./in. to allow for the rounding of the corners of the cross sections and other deviations from the idealized shape. Estimates by the students were generally nearer the lower value and usually thought by them to be accurate to within ± 5%.

At the end of the semester the class went to the Testing Materials Laboratory and conducted a short loading and unloading test on a washer and found that the spring constant was 1,800 lbs, per in.

Another year this problem might be extended in several ways. In the first place, a presentation of the results obtained the first year and perhaps a repetition of the experiment would enable another class to investigate the question of why the stiffness was higher than estimated. A second extension would be to ask the students to predict the stiffness of lock washers of different sizes leaving it to them to temper their theoretical estimates of the other sizes of lock washers with the experimental data obtained on the first one.

Brief experiments such as this can play a significant part in developing the student's judgment about the power and limitations of theoretical analysis.

APPENDIX B

A Problem in Thermodynamics

PROF. T. K. SHERWOOD

A gas well in New Mexico produces essentially pure CO_2 at 800 psia and 100° F. The pressure is reduced to 200 psia by flow through a partially closed ("cracked") valve and delivered by pipeline to a plant several miles away. The flow rate is steady at 10 million cu. ft. per day (reported as cu. ft. at 60° F. and 1.0 atm.).

The Joule-Thomson expansion through the adiabatic valve causes the gas to cool. This cold gas is used to provide refrigeration for a natural gasoline plant located near the wellhead. The condenser to be cooled operates at 60° F., and the minimum temperature difference for heat exchange is 5° F. (i.e., the warmed CO_2 leaves at 55° F.).

(a) What is the temperature of the CO_2 leaving the valve?

(b) What is the attainable refrigeration load, expressed as B.t.u. per hour?

(Comment: Note how the instructor has made this sound like a practical problem by the wording. This is pure camouflage—the solution is simple and straightforward. The student is not asked to think—only to know how to use the first law and the Mollier diagram for CO_2).

Solution

From the book, the first law flow equation is found to be:

$$Q - W_n = \Delta h$$

As applied to an adiabatic valve Q and W_n are zero, so the enthalpy leaving the

valve is the same as upstream. This is read from the Mollier diagram to be 146 B.t.u. per lb. CO_2. At 200 psia CO_2 has this enthalpy at 5° F., which is the answer to (a).

At 55° F. and 200 psia the enthalpy is 158 B.t.u. per lb., as read from the chart. In the condenser Δh is 158–146 or 12 B.t.u. per lb. CO_2. From the first law flow equation as applied to the condenser,

$$Q - 0 = \Delta h$$

so the refrigeration amounts to 12 B.t.u. per lb. CO_2 flowing.

The specific volume of CO_2 at 60° and 1.0 atm. is read from the chart as 9.2 cu. ft. per lb., so the CO_2 flow rate is:

$$\frac{10{,}000{,}000}{9.2 \times 24} = 45{,}300 \text{ lb. per hour}$$

The refrigeration load is then:

$$45{,}300 \times 12 = 543{,}000 \text{ B.t.u. per hour}$$

This is the answer to (b).

Use of the Same Problem to Teach Design

Now consider the problem so reworded as to invite the student to look at the design aspects of the situation.

The CO_2 flow rate is specified to be the same as before. The pipeline pressure is 200 psia, as before. Cooling water is available which can be used to cool the CO_2 stream to 70° F. The condenser to be cooled now operates at 20° F.; the cold gas can be warmed only to 15° F. so as to maintain the minimum temperature difference of 5° F.

The student is now asked: How much refrigeration is attainable from the CO_2 stream? How would the necessary equipment be arranged (i.e., draw a flow sheet)?

The routine M.I.T. student sees the statement regarding available cooling water, notes that the feed gas is the only thing capable of being cooled to 70°, and so refigures the problem with gas entering the valve at 70° F. and 800 psia.

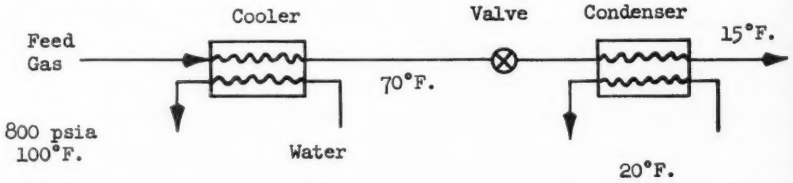
Enthalpy values from Mollier chart: feed gas, 146; gas at 800 psia, 70° F., 133; gas at 200 psia, 15° F., 148. Refrigeration is then:

$$45{,}300 \times (148 = 133) = 680{,}000 \text{ B.t.u./hr.}$$

and

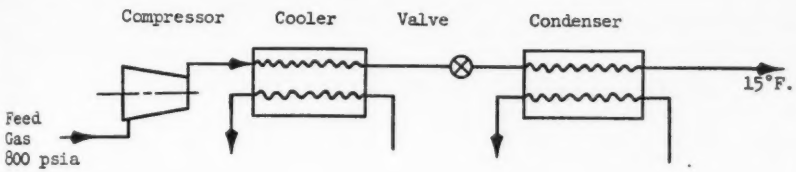
$$45{,}300\ (146 - 133) = 590{,}000 \text{ B.t.u./hr.}$$

are removed by the cooling water. The flow sheet is:



A *second* student goes through this same calculation but in doing so notices that the CO_2 leaving the valve is partly liquefied. This is evidently a good thing. If all the CO_2 could be liquefied, there would be a very large amount of refrigeration. But available cooling water limits cooling to 70°. The chart shows that CO_2 could be liquefied at 70° F. if the pressure were about 865 psia. The well pressure is only 800 psia. But it shouldn't take much power to compress the feed gas to 865 psia; the pump might be expensive because of the high operating pressure but would be physically small because the gas density is high and the volumetric displacement low.

This second student's flow sheet is:



The compressor is assumed to operate adiabatically and reversibly, and the pressure change is assumed to be isentropic. The first law gives the flow work as $-\Delta h$, which is read from the chart as approximately 2 B.t.u./lb. The theoretical power required is:

$$\frac{45{,}300 \times 2}{3412} = 26.7 \text{ kw, or } 35.6 \text{ h.p.}$$

which doesn't seem like much.

The CO_2 now leaves the cooler completely liquefied at 70° F. with an enthalpy of only 65 B.t.u./lb. Δh is zero through the valve, so the refrigeration attainable in the condenser is:

$$45{,}300\,(148 - 65) + 3{,}760{,}000 \text{ B.t.u./hr.}$$

The student doesn't know much about the efficiency or cost of compressors, but concludes that even if the actual power were twice the theoretical, the compressor installation would appear to be well worth while in view of the very large increase in refrigeration attainable.

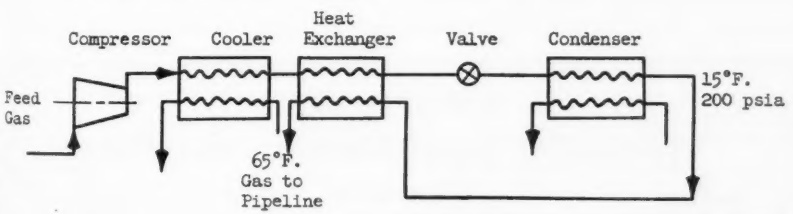
A *third* student follows the same reasoning and makes the same calculations as the second, but is troubled by the fact that the chart gives extremely poor precision in reading the Δh of 2 B.t.u. per lb. in the compressor. He has learned that if kinetic and potential energy terms are neglected, Δh for reversible flow is given as $-\int v dp$. Reading the chart, he finds the specific volume of the feed gas to be 0.115 cu. ft./lb. and that of the gas compressed isentropically to 865 psia to be about 0.105. An average value of 0.11 cu. ft./lb. can't be more than 5 per cent in error, so

$$\Delta h = 0.11 \times (865 - 800)\,\frac{144}{778}$$

$$= 1.32 \text{ B.t.u./lb.}$$

from which he calculates the theoretical (adiabatic reversible) compressor power to be 17.5 kw.

A *fourth* student makes the same calculations as the second or third student, but hates to see the gas go to the pipeline at 15° F. Cannot this cold gas be useful? Water cooling to 70° certainly was. Using the cold gas to partially cool the feed gas would only save cooling water. The thing to do, then, is to use the 15° gas to cool the liquid CO_2 leaving the gas-water heat exchanger. His flow sheet is as follows:



The cold gas is warmed in the heat exchanger to 65°, and leaves with an enthalpy of 161 B.t.u./lb. Since the mass flow is the same on both sides of the heat exchanger, the enthalpy decrease of the liquid CO_2 is the same as the enthalpy increase of the cold gas, which is (161 = 148) or 13 B.t.u./lb. The enthalpy of the liquid going to the valve (and entering the condenser) is

now (65 − 13) or 52 B.t.u./lb. So the refrigeration is:

45,300 (148 = 52) = 4,350,000 B.t.u./hr. The student recognizes that the high-pressure heat exchanger might be expensive (he suggests that the high pressure liquid would flow through tubes and the 200 psia gas through the shell) and doesn't know if the extra 590,000 B.t.u./hr. of refrigeration would warrant the cost of this additional piece of equipment (he hopes that he will soon get a course which will enable him to answer such questions).

Discussion

The possible ramifications of this sort of development of a thermo problem are enormous. But this is a course in thermodynamics and must move along—there is a lot more subject matter to cover. The problem has been a good workout in the use of a Mollier diagram and in the application of the first law flow equation to heat transfer equipment and to a Joule-Thomson expansion, as well as the calculation of isentropic compression power. The calculations are simple so as not to divert the student from the ideas introduced. Elementary concepts of process design are encountered (possibly for the first time), and the student has an opportunity to invent and compare alternative process schemes. There is a continuous feedback from analysis to better design.

There are many angles which can be developed in the discussion. The book and the course lectures have seemed to suggest that reversible processes are highly desirable. What are the irreversible features of the fourth student's flow sheet? Can they be reduced or eliminated? Can the common work functions ("availability") be used to calculate the operation of a wholly reversible process? Can a completely reversible process be described? Could an expansion engine be employed? Could the heat exchangers be made reversible, even with a zero temperature difference at one end? Is countercurrent flow in the exchangers desirable or necessary? What is the origin of the stipulation of a 5° F. minimum temperature difference? The second student found the high pressure gas to liquefy partially in passing through the valve. Is this phenomenon peculiar to CO_2? Could the book formulas for the Joule-Thomson coefficient be useful? What experimental procedures were employed to get the data on which the Mollier chart is based? If we had had no chart, could we have made useful calculations? Could we make a similar analysis for the case of a natural gas well (pure methane; or 90% methane, 10% ethane)? Would it be better to use a separate ammonia refrigeration plant, or possibly some combination of ammonia refrigeration plus Joule-Thomson expansion of the gas stream? Where would cooling water come from in New Mexico? What are water cooling towers and how do they work? Why 200 psia in the pipeline? Etc., ad infinitum.

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Survey of Engineering Economy Research in Educational Institutions

ROBLEY WINFREY

Chief, Highway Needs and Economy Research Division, U. S. Bureau of Public Roads, Washington 25, D. C.

At the ASEE meeting in Pittsburgh in 1959, members of the Division of Engineering Economy expressed an interest in knowing about the research work that might be under way in the subject area of engineering economy. It is my privilege to present some information which will indicate the research program in engineering economy at colleges and universities. This paper has the virtue of being brief, but its brevity is not by choice, but for the reason that my questionnaire study of 155 educational institutions produced little in the way of research in engineering economy to report upon. To my letter of April 4, 1960, to 155 engineering colleges and universities, 70 replies were received, 22 of which reported research under way, and 48 reported that no research was being conducted in the field of engineering economy. Eighty-five schools did not reply.

The 85 not replying was disappointing, and no reason is offered for the failure to reply. There is some indication, however, that the subject of research in engineering economy is not one of much concern to engineering professors in the 155 schools contacted, perhaps because so many departments and many professors have to do with economy, but few have sole or a major responsibility.

The questionnaire of April 4 was mailed to individuals who were members of the Engineering Economy Division of ASEE, heads of industrial engineering departments, to a personal acquaintance of mine, or to the Dean of Engineering. The selection was made on an individual basis, according to my judgment as to what individual would likely be the most cooperative.

Neither the letter of transmittal nor the questionnaire defines research. Neither did either paper define engineering economy. In each case the decision of what to report was the respondent's decision. The letter of transmittal did encourage the respondent to take a liberal interpretation of engineering economy and to include almost any subject related to private industry or public works which could be interpreted as coming within the subject of engineering economy.

Many of the replies apologized for not having research underway. Still others commented upon the teaching of engineering economy, and the particular courses offered. There is indication that the subject of engineering economy is of growing interest to the engineering

TABLE 1

Department	Number of Respondents	Number of Projects Reported
Industrial Engineering	10	17
Civil Engineering	3	6
Economics	3	4
Economics and Business Administration	2	4
Industrial Administration	1	1
Production Management	1	1
Electrical Engineering	1	2
Mechanical Engineering	1	1
Total	22	36

A paper presented at the 68th Annual Meeting of the American Society for Engineering Education, Engineering Economy Division, Purdue University, Lafayette, Indiana, June 21, 1960.

schools, and the future is likely to bring increased attention to this phase of engineering education.

A total of 36 research projects was reported from 22 institutions as shown in Table 1.

Of the 48 schools who reported that no research was under way, the information was furnished by professors in the following departments:

Mechanical Engineering	16
Engineering (no department given)	11
Industrial Engineering	6
Civil Engineering	3
Engineering Research	2
General Engineering	2
Electrical Engineering	1
Applied Science	1
Economics and Management	1
Petroleum Engineering	1
Provost office	1
Unknown	3
Total	48

Many of the replies indicated that the respondent made an effort to canvass the institution as a whole to uncover any research which could be classed as coming within the field of engineering economy. This procedure was in accordance with instructions.

Gerald J. Matchett [1] reported that 150 institutions out of 200 contacted were offering courses in engineering economy or equipment-replacement analysis. He received answers to his detailed questionnaire followup, however, from only 128 of these 150. The departments in which the course is taught are:

Industrial Engineering	34
Mechanical Engineering	22
Civil Engineering	17
Engineering and General Engineering	16
Industrial Management, Business, Economics	9
Electrical Engineering	6
Chemical Engineering	5
Other	5
Total	114

[1] "Engineering Economy Courses in Educational Institutions," *Journal of Engineering Education*, Vol. 50, No. 5 (February 1, 1960), pp. 418–423.

From this total and distribution by departments, it would be reasonable to expect more research in engineering economy and a higher percentage of replies.

On the hope that there might be some correlation between the number of degrees, particularly graduate degrees, granted in the school year 1958–1959 in industrial engineering, a comparison was made of the replies to the questionnaire with the schools granting degrees in industrial engineering. The schools reporting research and granting bachelors degrees, but not graduate degrees, in industrial engineering were fewer in number and proportionally fewer in number than were the institutions granting graduate degrees in industrial engineering and reporting research in engineering economy.

Of the 22 institutions reporting research under way, 5 did not grant any degrees, undergraduate or graduate, in industrial engineering in the 1958–1959 school year.

The summary statistics are: Of the 22 institutions reporting research projects in engineering economy,

10 granted graduate degrees in industrial engineering in 1958–1959,
7 granted only undergraduate degrees in industrial engineering in 1958–1959,
5 granted no degrees in industrial engineering in 1958–1959.

Of the 48 institutions reporting no research projects in engineering economy,

6 granted graduate degrees in industrial engineering in 1958–1959,
12 granted only undergraduate degrees in industrial engineering in 1958–1959,
30 granted no degrees in industrial engineering in 1958–1959.

The 94 institutions granting degrees in industrial engineering in 1958–1959 are related to the questionnaire study on research in engineering economy as shown in Table 2.

TABLE 2

	Undergraduate degrees only	Graduate degrees	Total
Reported research projects	7	10	17*
Reported no research	12	6	18
Did not reply	36	23	59
Total	55	39	94

* Five other schools did not grant degrees in industrial engineering but reported research projects.

The indications are that research interest in engineering economy is largely one of a personal nature. That is, research in engineering economy is to be found at those institutions where there is a professor of engineering economy, or of industrial engineering, or of another department of engineering who has a research interest and an interest in engineering economy.

The general lack of interest in research in engineering economy perhaps is indicated by the fact that Part C of the questionnaire provided opportunity to list suggestions and explanations for research in engineering economy which someone should undertake. Only 4 respondents took opportunity to offer suggestions in the field of needed research in engineering economy. The suggested studies are attached.

No attempt is made in this paper to indicate the amount of research in engineering economy that may be under way in the whole number of institutions. Only the specific 36 projects reported are listed in this paper. Whether or not the 85 institutions making no reply to the questionnaire and institutions not contacted have research underway is unknown.

The attached listing (Appendix B) is a verbatim report of the information furnished on the 36 research projects under way at educational institutions in April of 1960. The 36 listed projects are divided as follows by general sponsorship:

Faculty members personal project	10
M.S. student thesis subject	10
Industry and government	6
Ph.D. student thesis subject	4
Institution project	2
Unknown	4
Total	36

Appendix A

SUGGESTED RESEARCH STUDIES

1. Revision of Service lives, Bulletin F. Col. J. C. Hempstead, U. S. Air Force Academy.
2. Rate of return—a sliding scale that will reflect changing rates of pure interest with no risk. Col. J. C. Hempstead, U. S. Air Force Academy.
3. To what extent principles of engineering economy are being used in consulting practice. William G. Barney, University of North Dakota.
4. Cost of capital—in business and government. C. H. Oglesby, Stanford University.
5. A method for handling inflation of the dollar in engineering economy studies. Harold A. Cowles, Iowa State University.
6. "Make or buy" and "lease or buy" studies. Harold A. Cowles, Iowa State University.
7. Shifting the emphasis of engineering economy studies from the mechanics of compound interest to the methods of estimating (labor savings, equipment lives, inclusion or exclusion of overhead, etc.). Harold A. Cowles, Iowa State University.
8. Determine the opinions of the management of different types of industries relative to whether or not the inclusion of engineering economics is desirable in an electrical engineering curriculum. J. J. Carey, University of Michigan.
9. Practices and effects of using models of study and methods of arriving at cost in economy studies that are different from models and methods used in company accounting. John R. Canada, Virginia Polytechnic Institute.

Appendix B

SURVEY OF RESEARCH RELATED TO ENGINEERING ECONOMY CONDUCTED AT EDUCATIONAL INSTITUTIONS

1. Arizona State University
   Department of Industrial Engineering
   Professor C. B. Gambrell
   Title: Clarification of Various Engineering Economy Concepts
   Objective: To clarify and/or quantify some of the conventional engr. econ. concepts as presented in the more popular texts.

2. Clarkson College of Technology
   Department of Mechanical Engineering
   Professor George Maclean
   Title: (Proposed) The Optimization of Capital Investment in Productive Facilities
   Objective: Propose a method of investment analysis based on probabilistic parameters of "internal and external obsolescence" and analysis of alternatives utilizing mathematical programming, recognizing investment as a substitution for labor.

3. Duke University
   Department of Economics and Business Administration
   Professor Thomas F. Keller
   Title: The Inter-Period Allocation of the Corporate Income Tax
   Objective: To develop a theoretical basis for the allocation of the corporate income tax on a basis consistent with accepted accounting theory.

4. Illinois Institute of Technology
   Department of Business and Economics
   Professor G. J. Matchett
   Title: Decision Making Among Business Investment Alternatives
   Objective: Study of economics of new facility acquisition, and replacement.

   Illinois Institute of Technology
   Department of Business and Economics
   Professor G. J. Matchett
   Title: Project Justification Analysis in a Small Food Products Firm
   Objective: To provide a realistic case study.

   Illinois Institute of Technology
   Department of Business and Economics
   Professor G. J. Matchett
   Title: Economics of Replacement of Transportation Equipment
   Objective: Application of replacement theory to special cost characteristics of transportation equipment.

5. Iowa State University
   Department of Industrial Engineering
   Professor W. R. Moore
   Title: An Operations Research Approach to the Problem of Optimizing Waste Created in the Casting, Coating and Trimming of Cellophane
   Objective: To determine if savings in waste can be accomplished by changing some methods of operation and modifying existing measures of performance.

   Iowa State University
   Department of Industrial Engineering
   Professor Harold A. Cowles
   Title: Regulatory Policies on Accelerated Depreciation Methods and Their Effects Upon Public Utilities
   Objective:
   1. Survey frequency of usage of SOYD & DDB methods
   2. Determine whether methods produce permanent or temporary savings
   3. Find effect of commission policy on public utilities' selection of depreciation method.

   Iowa State University
   Department of Industrial Engineering
   Professor Harold A. Cowles
   Title: Moment Ratio Method for Analyzing Industrial Property Experiences
   Objective:
   1. Study and try to develop use of moments as basis for comparing dispersion patterns
   2. Devise methods whereby Iowa Type Survivor Curves can be used more readily with mathematical, and, hence, machine, procedures.

6. Kansas State University
   Department of Industrial Engineering
   Professor John P. Clifton
   Title: Small Business Management Strategy (Manufacturing)
   Objective: To determine management strategems that have enabled small manufacturers to acquire and maintain a competitive and sound financial position under changing conditions.

7. Maryland University
   Department of Economics
   Dr. Daniel Hamberg
   Title: Patterns of Invention

Objective: To find out more about where significant new inventions come from—large laboratories, small firms, individual inventors; suggestions to speed up rate of growth in Gross National Product.

8. Massachusetts Institute of Technology
No detail given on their large program.

9. Michigan University
Department of Electrical Engineering
Professor J. J. Carey
Title: Application of the Digital Computer in the Determination of the Rate of Return After Income Taxes (for a Project for Which the Costs and the Incomes Are Known for a Definite Period of Years).

Michigan University
Department of Electrical Engineering
Professor Harry H. Goode and Dr. Tanner
Title: Delineation of the Various Areas of Decision and Their Application to Various Program Areas of Decisions such as Business, War, Sensory Perception, etc.

10. Missouri School of Mines and Metallurgy
Department of Civil Engineering
Professor Clifford D. Muir
Title: Regulation of River Bank Development Through Flood Plain Zoning
Objective: Developing of criteria for flood plain zoning and an economic evaluation.

Missouri School of Mines and Metallurgy
Department of Civil Engineering
Professor E. W. Carlton
Title: Application of Accepted Principles of Engineering Economy to the Economic Justification Practices of the Corps of Engineers on Construction Projects
Objective:
(a) Economic evaluation—the benefit-cost ratio;
(b) Establishing scale of development;
(c) Consideration of other available means;
(d) Analysis of justification;
(e) Comparison of relative economic value of justified projects.

11. North Dakota State College
Department of Industrial Engineering
Professor Marion B. Richardson
Title: Technological Forecasting
Objective: Forecast development of engineered products to assure designs and capital investment within capabilities of consumer use.

North Dakota State College
Department of Industrial Engineering
Professor Marion B. Richardson
Title: A Survey and Study of North Dakota's Potentials for Industrial Economic Development.
Objective: Study and review in detail the advantages and disadvantages relative to the establishment and growth of manufacturing and industrial processing.

12. Northwestern University
Department of Production Management
Dr. Myers
Title: A Method of Analyzing Automation Proposals
Objective: At the present time a comprehensive and broad method of analyzing major expenditures is not readily available to businessmen. The objective of this study is to develop one.

13. Ohio State University
Department of Industrial Engineering
Professor William T. Morris
Title: Research in Engineering Economy
Objective: This is a long term project which attempts to make the problems treated by engineering economy more realistic.

14. Oregon State College
Department of Industrial Engineering
Professor William Engesser
Title: Inventory Control
Objective: Sales forecasting.

15. Rensselaer Polytechnic Institute
Department of Economics
Dr. Seymour Sacks
Title: The ways in which business handles depreciation.

Rensselaer Polytechnic Institute
Department of Economics
Dr. Seymour Sacks
Title: Oligopoly pricing in industry.

16. University of Southern California
Department of Industrial Engineering
Professor C. W. Whitston
Title: Internal Cost Control Within Advertising Agencies
Objective: Application of incentives on cost controls.

Southern California University
Department of Industrial Engineering
Professor W. F. Girouard
Title: Analog Simulation of a Linear Programming Model

Objective: To develop a method for using an analog computer to provide a continuous solution of a linear model.

University of Southern California
Department of Industrial Engineering
Professor W. F. Girouard
Title: Operational Control System
Objective: Development of an industrial data collection and processing system utilizing electronic data collection equipment and a medium size digital computer. This research is being conducted at a company with a heavy product mix, a large number of parts per unit and few of each unit produced. The company is engaged in the production of computers for the military.

17. Stanford University
Department of Civil Engineering
Professor R. K. Linsley
Title: Economics of Flood Control on San Francisquito Creek, California
Objective: To illustrate application of engineering economy to flood control and to test sensitivity of procedures.
Stanford University
Department of Industrial Engineering
Professor E. L. Grant
Title: A Critique of Compound Interest Models Used in Decision Making for Capital Budgets
Objective: To analyze recent criticism (mostly theoretical) of compound interest techniques from a practical capital budgeting standpoint.
Stanford University
Department of Civil Engineering
Professors E. L. Grant and C. H. Oglesby
Title: Application of the Principles of Engineering Economy to Highway Improvement
Objective: To develop the concepts and principles of engineering economy as they apply to highway engineering. To develop typical examples (and their solutions) of highway economy studies.

18. Stevens Institute of Technology
Department of Industrial Engineering
Professor J. E. Ullmann
Title: Criteria of Machinery Replacement
Objective: Segregation of machine replacement cases into worn-out machinery, expansion for new business and introduction of new processes. Category I is seen to predominate.

Stevens Institute of Technology
Department of Industrial Engineering
Dr. Arthur Lesser, Jr.
Title: Planning, Administration and Control of Capital Expenditures
Objective: A pilot study to define the area of capital investment in all of its ramifications in the context of the business firm. Some of the questions I expect to answer in a preliminary way are the common elements of investment in different industries and different types of companies, as well as characteristics that differentiate among the various approaches.

19. Syracuse University
Department of Industrial Engineering
Professor R. O. Swalm
Title: Study of Replacement Policy and Implementation
Objective: Study of above in specific industrial enterprise.

20. Virginia Polytechnic Institute
Department of Industrial Engineering
Dr. Roger L. Smith
Title: Breakdown Study of Manufacturing Costs
Objective: To derive a convenient means of estimating actual costs incurred in producing differential orders.

21. University of Wisconsin
Department of Civil Engineering
Dr. L. W. Crandall
Title: Discount Rate in Engineering Economy Analyses
Objective: To establish correct "Cost of Money" for use by engr. department of electric power company considering (a) taxes increase cost of money, (b) taxes decrease cost of money, (c) taxes do not affect cost of money.
University of Wisconsin
Department of Civil Engineering
Dr. L. W. Crandall
Title: Engineering Economy Course (with company manual, procedures, problems) Tailored to Specific Interest Rates and Considerations (ie; purchase vs. lease)
Objective: To develop company course for Wisconsin Power & Light Company to be taught to continuing groups of 20 in this order: managers, engineers, business development men, sales personnel.

22. Yale University
Department of Economics—Cowles Foundation
Professor Jacob Marschak in charge of project

Professor Alan S. Manne—reporting on his own research
Title: Decision Making Analysis
Objective: Perform basic research in disciplines related to decision-making. Manne has specialized in single-person decision problems (operations research, etc.), but the project as a whole is concerned with multi-person problems (organization theory) too.

Yale University
Department of Industrial Administration
Professor Robert B. Ritter
Title: The Planning of Industrial Service Facilities
Objective: Through model building and analysis to determine methods for establishing optimal levels of such service facilities as maintenance and materials handling.

SPINDLETOP

Visitors to the annual meeting at Lexington in June will get a look at Kentucky's unique effort to attract industry to the state.

The Universiy of Kentucky, state government, and private industry have joined promotional hands in creating on University property a physical complex of industrial research laboratories and complementary facilities.

Known as the Kentucky Spindletop Research Center, the site is situated on 425 acres of valuable Blue Grass soil carved from historic Spindletop Farm which is owned by the KRF, an agent of the University. There are 1,066 acres in the former thoroughbred horse farm located some 5 miles from Lexington. It was purchased by UK in 1959 for the "gift" price of $850,000.

Nucleus of the Research Center will be the Spindletop Research Institute, a central building area of 75 acres on which will be located the University-owned administration building and research laboratory. This 3-story structure of prize-winning design will be the architectural point of reference for future Research Institute buildings. It is being constructed directly across the lake from a future motel group and the lakeside end of a group of four buildings including a library, restaurant and auditorium.

The 350 acres adjacent to the University nucleus will be made available to private industrial firms for their own research laboratories.

Final control of the Institute will rest with the University, and under it as managing agency will be the Kentucky Research Foundation, an independent, nonprofit organization created some years ago to handle research and promotion for the University.

Directing the Center will be a 55-man board which includes leading national and Kentucky industrial figures, who will be the private enterprise voice in the operation.

A total of $1,327,000 in public money is earmarked for the project to cover cost of the central building utilities, other improvements and cost of the land.

Amount of private capital to be invested depends entirely on how many concerns are attracted to the Center. If private industry takes all 350 acres set aside for it, the investment could go into many millions of dollars.

Private industry research facilities will be entirely separate from any of the University building but not all industries using the Center are expected to build their own laboratories. Some undoubtedly, will have the University do research for them on a contract basis. There is to be no manufacturing at the Center.

A 10-year building program for the Center is envisioned by Kentucky's Lt. Governor Wilson W. Wyatt, who played a leading role in establishing the project. He has described the overall project as "possibly one of the most important developments in the modern life of the state."

Only North Carolina with its Research Triangle in proximity to Duke, North Carolina State and the University of North Carolina has anything which resembles the Kentucky project.

The Industrial Engineering Curriculum Today

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West Virginia University
Morgantown, West Virginia

During the research on a study of the undergraduate industrial engineering curricula for a master's thesis, the need arose to examine the present curricula in the engineering schools of the United States. It was felt that a comparison of the present day curricula with those of 1937–1938 as revealed in a study by H. B. Shaw [1] at North Carolina State would be of interest, and that this data would be of interest also to people dealing with the accreditation of engineering education.

It was decided to limit the study to the curricula of ECPD-accredited schools offering either degrees in industrial engineering (37 schools) or industrial options from mechanical engineering (15 schools). The study was compiled by making a comprehensive survey of the accredited departments as well as a study of their 1958–1959 catalogs. Three schools were not included in the tabulations, one stating that an industrial engineering curriculum did not exist, one because it did not have a regular 4- or 5-year curriculum, and another because its high total of credits in its 5-year curriculum did not allow comparison with other schools.

All of the curricula were reduced to the semester-hour basis on the ratio of 2 credits under the semester system equaling 3 credits under the quarter system. Comparison of curricula was difficult because of (1) the large amount of variation in course titles for essentially the same course, (2) the lack of consistency in course titles and apparent course content, (3) the different systems for assigning course credits, and (4) the practice of some schools of combining a group of subjects into one course. In the last instance, credits were either assigned to several subjects or were assigned to the miscellaneous category.

One problem encountered was that of how to handle the credits for military training, physical education, and some of the introductory mathematics courses. The proposal of dropping these courses from the total credits was considered, but it was felt that this would be misleading since these schools would, in most cases, add credits to other subject areas if they were to drop these subjects. A total of gross credits was calculated, then a net figure was obtained with military science and physical education deleted.

The curriculum at each school was divided into 6 divisions, Basic Science, Humanities and Social, Engineering Science, Other Engineering, Electives, and Industrial Engineering. The breakdown into these divisions is based on current nomenclature. The same divisions were applied to H. B. Shaw's 1937–1938 report so that a comparison could be made with the information compiled by this study.

The total gross semester-hour credits as seen in Figure 1 vary from 122 to

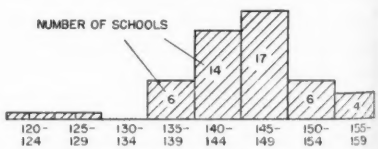

FIG. 1. Total Gross Credit Range at ECPD-Accredited Industrial Engineering Schools.

[1] "Comparative Analysis of ECPD Curricula for College Year 1937–1938," Unpublished Paper, North Carolina State College, 1938.

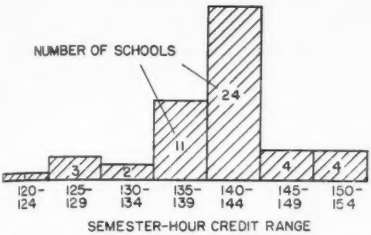

FIG. 2. Total Net Credit Range at ECPD-Accredited Industrial Engineering Schools.

158 with 96% ranging from 136 to 158. The mean of the gross credits is 145. Although not perfectly so, the distribution is approximately normal. The net credits have extreme values from 122 to 154 with 71% falling between 136 and 144. The mean of the net credits is 140 and is borne out in Figure 2. Again the distribution is approximately normal.

Table 1 has been prepared to show an analysis of the 1958–1959 industrial engineering curricula at 49 ECPD-accredited schools.

General Discussion of Curricula

Figure 3 shows a summary of the semester-hour credits for 1958–1959 as compared to Shaw's 1937–1938 study. Figure 3 shows that Basic Science has had a loss of 1% for this period of time, dropping from 25% to 24%. Humanities and Social courses have also lost 1% since 1938. Engineering Science has decreased from 21% in 1938 to 19% in 1959. Courses in Other Engineering have also increased from 8% to 9%. Electives have decreased from 11% of the curriculum in 1938 to 10% at the present time. Industrial Engineering subjects have increased from 15% in 1938 to 19% in 1959.

While reviewing the catalogs of ECPD-accredited schools, some facts of general interest were noted. Approximately 7 of the schools require attendance at one summer session. Several schools offer Industrial Engineering options, including a Law option at the University of Tennessee and a Production Engineering option at Pennsylvania State University. The University of Alabama has a Foundry option; Renssalaer Polytechnic Institute offers options in Aeronautical Engineering, Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, or Metallurgical Engineering, in which the student takes a sequence of 7 courses in the last 3 years. New York University has a similar program of 5 technical options, which require from 15 to 18 semester hours.

Johns Hopkins has a plan of options which includes programs within special-

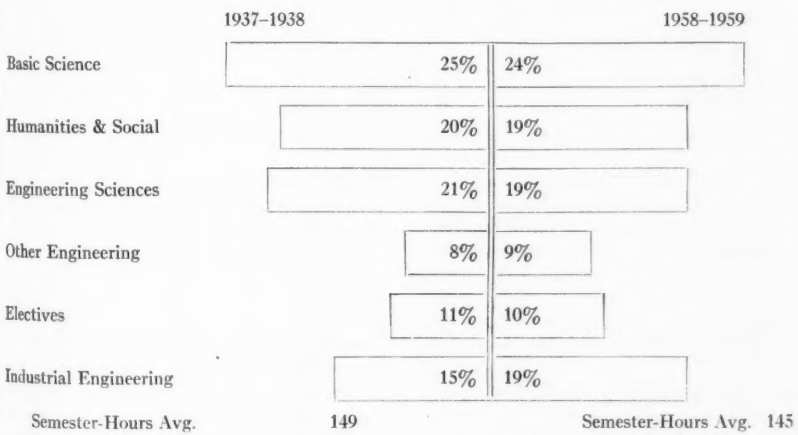

FIG. 3. Comparison of ECPD industrial engineering curricula of 1937–1938 and 1958–1959.

TABLE 1

COMPARISON OF 1958–1959 INDUSTRIAL ENGINEERING CURRICULA

	Schools		Credits	
	Number	Percentage	Average	Range
Basic Science				
Chemistry	49	100.0	7.8	4–11
Mathematics	49	100.0	17.1	12–22
Physics	49	100.0	10.4	4–14
Total Basic Science			35.2	26–44
Humanistic & Social				
English	47	96.1	6.6	2–12
Economics	41	83.8	3.8	2–9
Basic Accounting	40	81.7	3.4	2–12
Cost Accounting	28	57.2	2.8	2–3
Speech	29	59.2	2.2	1–4
Psychology	22	45.0	3.5	2–9
History	21	42.9	5.2	2–11
Political Science	14	28.6	4.3	2–8
Humanities	10	20.4	10.3	5–32
Business Law	7	14.3	2.9	2–3
Sociology	4	8.2	4.0	2–6
Marketing	4	8.2	3.0	2–4
Religion	3	6.1	4.3	3–6
Philosophy	2	4.1	4.5	3–6
Military Science	31	63.3	5.9	2–9
Physical Education	22	45.0	3.2	1–6
Total Humanistic & Social			28.3	11–46
Engineering Sciences				
Mechanics	48	98.1	5.6	2–12
Elec. Engr. & Lab.	47	96.1	7.0	4–14
Strength & Materials	46	94.0	3.9	1–7
Thermodynamics	45	92.0	4.3	1–11
Statistics	35	71.5	3.9	2–10
Metallurgy	32	65.4	2.9	1–6
Hydraulics	29	59.3	3.1	2–4
Mech. Engr. Lab.	18	36.8	1.5	1–3
Kinematics	15	30.6	2.8	2–3
Total Engineering Sciences			27.8	10–40
Other Engineering				
Drawing	48	98.1	3.4	1–7
Descriptive Geometry	30	61.2	2.4	2–3
Machine Design	34	69.5	4.3	1–11
Shop Work	25	51.2	3.2	1–9
Orientation	12	24.5	1.5	1–6
Surveying	6	12.2	2.1	1–4
Modern Physics	13	26.6	2.7	2–3
Technical Writing	10	20.4	2.6	2–4
Thesis	6	12.2	2.7	1–6
Higher Mathematics	6	12.2	3.0	2–4
Other Miscellaneous	13	26.6	2.7	1–4
Total Other Engineering			12.5	4–27

TABLE 1—*Continued*

	Schools		Credits	
	Number	Percentage	Average	Range
Electives				
Humanities	35	71.5	8.7	3–24
Technical	20	40.8	6.0	3–12
Unspecified	21	42.9	8.4	3–13
Ind. Engr. Electives	9	18.4	8.2	3–25
Total Electives			14.0	3–44
Industrial Engineering				
Principles of I. E.	45	92.0	3.1	2–7
Motion and Time Study	43	88.0	3.1	2–7
Mfg. Processes	38	77.7	3.1	1–5
Engineering Economy	38	77.7	2.7	2–4
Plant Layout	38	77.7	2.8	2–4
Production Control	37	75.7	2.9	2–6
Quality Control	28	57.2	2.7	2–6
Seminar	26	53.2	1.7	1–5
Industrial Relations	17	34.8	3.1	2–7
Tool Design	16	32.7	2.5	2–5
Engineering Problems	14	28.6	2.0	1–3
Job Evaluation	13	26.6	2.4	2–4
Safety	10	20.4	2.2	1–3
Law & Ethics	10	20.4	2.2	1–5
Cost Estimating	9	18.4	2.5	2–3
Materials Handling	7	14.3	2.0	1–3
Engineering Analysis	8	16.4	3.7	2–6
Data Processing	8	16.4	3.0	2–4
Human Relations	6	12.2	2.1	2–3
Inspection Trips	5	10.2	1.6	1–3
Methods & Standards	5	10.2	2.9	2–4
Operations Research	5	10.2	3.2	2–6
Linear Programming	4	8.2	2.8	2–3
Surveying & Reports	4	8.2	1.6	1–3
I. E. Design	5	10.2	4.2	2–8
Personnel Management	3	6.1	2.9	3–3
Report Writing	4	8.2	2.8	2–3
Automation	2	4.1	2.9	3–3
Miscellaneous	20	40.8	4.4	2–20
Total Industrial Engineering			26.9	10–48

ized areas of Industrial Engineering. A student may concentrate on Accounting, Human Engineering, Labor Relations, Operations Research, or Statistics.

Discussion

Several trends were evident after examining the data and discussing the curricula with many of the department heads. For example, there was overwhelming support for more emphasis on basic principles and fundamentals as opposed to techniques. This trend is obvious by a reduction in average credits in drawing from 5.1 to 3.4, a reduction in schools offering Shop Work from 75% to 51% and a decrease in average credits in Shop Work from 6.1 to 3.2. This trend is further substantiated by a reduction in schools offering Surveying from 50% to 12%.

Another trend noted was the rapid growth of Statistics, from one school offering it out of 16 in 1937–1938 to 35 of 49 offering it in 1958–1959. Also

evident was the addition of new concepts to the curricula such as Electronic Data Processing, Linear Programming, Solid State Physics, Operations Research, and Quality Control. An increased emphasis in mathematics was also noted.

Summary

In summary, it is apparent from the evidence produced in the text and tables that there is at present no standard industrial engineering curriculum. The wide spread in credits for the various courses revealed in Table 1 indicates that much work would have to be done in the future to attain any great degree of standardization, if this is desired. The changes in the industrial engineering curricula during the last 20 years show that considerable effort has been made to gear the curricula to rapid advances being made in industry as well as science.

Candid Comments

This section is open to comments on articles in the JOURNAL or on engineering education in general. Send comments to the Editor, JOURNAL OF ENGINEERING EDUCATION, University of Illinois, Urbana, Illinois.

Deflection of Beams

It may be of historical interest that the substance of Prof. Niedenfuhr's note in the JOURNAL OF ENGINEERING EDUCATION, vol. 50, no. 3, on the solution of the linearized beam deflection equation, already appears to have been investigated by R. Macaulay, King's College, Cambridge (*Messenger of Mathematics*, Jan. 1919).

Macaulay's elegant solution, applied to a beam of constant flexural rigidity EI, loaded with n concentrated transverse loads P_i at respective distances a_i from the origin at one end of the beam, results in

$$EIv = \sum_{r=0}^{3} C_r x^r - \sum_{i=1}^{n} \frac{P_i}{6} \{x - a_i\}^3$$

where

$$\{x - a_i\} = x - a_i \quad \text{if} \quad x > a_i$$
$$= 0 \quad \text{if} \quad x \not> a_i.$$

The method is described and extended to discontinuous distributed load functions and to concentrated couple loads in *Strength of Materials* by J. Case (Arnold, London, 1925).

I should like to take this opportunity of making a plea for the use in Introductory Strength of Materials of the symbol v for beam deflection (in the y-direction) instead of the usually-used y. In my teaching experience I have found that the use of the same symbol y, both for y-deflection and for y co-ordinate, has been a source of confusion to students. Furthermore, the introduction early in the course of the notation u, v, w for the x, y, z components respectively of deflection, has proved to be a painless way of preparing the student for the "elasticity" expressions for strain.

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San Diego State College

Current Philosophies and Instruction in Experimental Mechanical Engineering and Design Courses

A Selected Bibliography

A. K. JOHNSTON
R. L. ESHLEMAN
T. E. JACKSON
J. B. HARTMAN
Project Director

Educational Philosophy

1 L. M. K. Boelter, "Some Observations on Learning," *J. Eng. Educ.*, vol. 37, no. 5, January, 1947.

Reviews theory of learning at date (1947), giving equations etc. for learning rates. Extensive list of references as to psychology of learning.

2 G. F. Mucklow, "Universities and Education of Engineers," *Inst. Mech. Engrs., Proc.*, vol. 164, no. 4, pp. 396–8, 1951.

General discussion of problems and deficiencies in England. Importance of graduate schools being established in Great Britain. Philosophy: "It is the outlook and attitude of mind engendered, not the subjects studied, that matter." Author feels that study of humanities in engineering courses is unnecessary. Student who is not already interested in humanities because of home and school, never will be.

3 P. J. Wallace, *The Technique of Design*, Pitman, 1952.

4 ASEE, "Improvement of Engineering Teaching," *J. Eng. Educ.*, vol. 43, no. 1, pp. 33–46, September, 1952.

(Part C—The Project Method, pp. 40–42.) A brief discussion on the project method of teaching in the laboratory and classroom.

5 L. E. Grinter (Chairman), "Improvement of Eng. Teaching," *J. Eng. Educ.*, vol. 43, no. 1, September, 1952.

Report of ASEE committee. Describes objectives and gives definitions of terms. Enumerates principles of teaching and learning. Suggests more extensive use of project method, seminars and laboratory work. Makes suggestions as to training of instructors. 1. Staff meetings 2. Regular supervision by senior instructor 3. Recognition of good teaching 4. Establishment of a school for engineering teachers.

6 N. P. Bailey, "What Are Contemporary Demands on Eng. Curricula," *J. Eng. Educ.*, vol. 43, no. 5, pp. 303–6, January, 1953.

Analysis of the eng. curriculum.

7 T. K. Sherwood, "Should Engineering Schools Teach Engineering?", *J. Eng. Educ.*, p. 383, March, 1953.

Engineering curriculum is designed primarily to teach men what they need to know in order to start learning something about engineering. Suggestion that creative

Interim report of the Department of Mechanical Engineering, Lehigh University, on a Project supported by a grant from the National Science Foundation.

engineering project type of instruction be adopted to give engineering students practical training required.

8 K. B. McEachron, Jr., "Why Options Anyway?", *Elec. Eng.*, vol. 72, no. 4, pp. 305–6, April, 1953.

Stressing fundamental principles in undergraduate engineering education, options as they now stand tend to distract student from fundamentals. Author puts forward a case for giving students options in freshman year. Options to be designed so that student is not only motivated, but his attention is *drawn to fundamentals* and their importance.

9 "EUSEC Conference on Engineering Education," *Mech. Eng.*, vol. 75, no. 5, pp. 395–6, May, 1953.

Views of representatives from Eng. Soc. of U. S. and Western Europe exchanged regarding place of basic science and technological studies.

10 Charles D. Flory, "Developing and Using Our Creative Abilities," *Chem. Eng. Progress*, December, 1953.

Essence of creativity on part of scientists and others; distinctions between creative thinking and reflective thinking; factors which act as impediments to creativity; characteristics of creative people.

11 H. G. H. Tracey, "The Training of Engineering Designers," *The Engineer*, vol. 195, p. 884, 1953.

Describes gratifying experiences with the "design and make" type of projects in teaching machine design. Class divided into teams who carry out complete design and manufacture.

12 L. M. K. Boelter, and G. A. Hawkins, "General Mode of Analysis in Engineering Education," *J. Eng. Educ.*, p. 343, January, 1954.

A general method of analysis to be introduced to the engineering student early in his academic career with constant use throughout remaining courses. "Approaches used in the general mode of problem solution:" 1. Analytical 2. Experimental 3. Art 4. Models and Analogues.

13 W. S. Rouverol, "A Look at British Technical Training," *Mech. Eng.*, vol. 76, no. 2, p. 170, February, 1954.

The British education system is described in detail with a comparison to the American system.

14 James N. Thurston, "Engineering Laboratory Courses," *J. Eng. Educ.*, vol. 44, no. 8, pp. 421–2, April, 1954.

General laboratory philosophy.

15 L. E. Grinter, "Industry's Interest in More Education for Engineers," *J. Eng. Educ.*, p. 499, May, 1954.

Definition of the need for better trained engineers for industry, their past and present attitudes toward education and the present opportunities which are present for the graduating student.

16 Charles H. Dawson, "Servomechanisms in the Undergraduate Curriculum," *J. Eng. Educ.*, vol. 44, no. 10, pp. 617–19, June, 1954.

Integration of fundamentals by teaching a course in feedback controls.

17 Walter Rogers, "Leadership Training in the Laboratory," *J. Eng. Educ.*, vol. 44, no. 10, pp. 651–2, June, 1954.

General laboratory philosophy.

18 James J. Ryan, "Vibration Problems," ASEE Paper presented June 23, 1954.

Philosophy of teaching vibration theory and current need for use of fundamentals in solution of problems.

19 E. M'Ewen, "Training of Engineering Designers," *Engineer*, vol. 198, no. 5142, pp. 221–3, August 13, 1954.

Criticizes tendency to steer bright students into "mathematical" curricula instead of design in England.

20 J. F. Downie Smith, "Improving the Teaching of Engineering," *J.*

Eng. Educ., p. 73, September, 1954.

Need for synthesis as well as analysis in design. Originality by the project method. The educational philosophy and analysis of engineering teaching needs changing so as to develop more creative thinking.

21 J. A. Hrones, "Role of Measurements and Instrumentation in Engineering Education," ASME Paper, no. 54 IRD-8, for meeting September 13–24, 1954.

Importance of engineering quantities and measurements. Instrumentation subjects should be integrated into existing courses rather than taught separately. Use of block diagrams and concept of closed loop and feedback should be introduced early. Suggests a travelling instrumentation exhibit be prepared by ISA and sent round to various engineering schools.

22 A. Boyajian, "Practice Course for Engineering Students," *Elec. Eng.*, vol. 73, no. 10, pp. 868–9, October, 1954.

MIT projects and problem- solving course for electrical engineering. This author suggests a project type course which has a topic not associated with one's major field of study. This course would help the future engineer to gain knowledge on his own.

23 A. Bronwell, "Basic Conflicts in Engineering Education," *Mech. Eng.*, vol. 76, no. 11, pp. 886–90, November, 1954.

A discussion on: science vs. practice in engineering education; the monolithic concept of education; duplication of subject material. A penetrating look at American eng. educ.

24 E. G. Reed, "Developing Creative Talent," *Machine Design*, p. 142, November, 1954.

Analysis of traits needed for the development of creative ability: educability, perception, analysis, creativeness, initiative, judgment. "Creative ability grows out of the fatigue of analysis." Fatigue, which helps trigger the creative state, can be induced by prolonged physical and mental work."

25. D. L. Trautman, "Engineering Education across the Country," *J. Eng. Educ.*, p. 274, November, 1954.

Some observations made by the author on a nationwide tour of colleges and universities. 1. It appears that the nature of eng. educ. is almost everywhere the same—training for routine doing. 2. Potentialities of the student as a learner or as a creative individual in general are not exploited. 3. The vigorous evolution of engineering education is hampered by: A. complacent, inbred and conservative teachers, B. dissonant administrative framework, and C. a blurred view of the essence of eng. educ. 4. Despite the general complacency, educational experimentation does exist. Methods of stimulation of eng. educ. given as directions in which to pursue answers to problems stated.

26 Lee Harrisberger, "Teaching Design by Motivation," *J. Eng. Educ.*, vol. 45, no. 4, p. 367, December, 1954.

A modified project method used in machine design course to motivate maximum attainment. "Design is not an art—it is the act of putting a lot of related facts together and making decisions as to which facts are important. To teach design is to teach thinking, reasoning and self reliance. Motivation is the key to learning. Therefore, give the student a mature challenge and his natural enthusiasm will motivate him to learn the most difficult of all—the ability to reason."

27 ASEE, *Educational Aids in Engineering*, brochure, March, 1955.

Prepared by a committee of ASEE, covers aids in civil, electrical, mechanical, mechanics, mathematics. Embraces films, film-

strips, diagrams, demonstration/laboratory equipment. In mechanical engineering, some interesting items are: Stodola's nozzle apparatus with exploring tube, epicyclic gear trains, fluid mechanics—films on smoke diffusion, wind curtains, turbulence, cavitation, flow phenomena (Prandtl) hydraulic demonstrator—closed conduct and open channel, and magnus effect demonstrator. Introduction gives (among other things) useful criteria for judging and analyzing value of educational aids, and makes a plea for more attention to development of aids.

28 John E. Gibson, "Conference Method in Laboratory Courses," *J. Eng. Educ.*, vol. 45, no. 7, pp. 540–1, March, 1955.

Advantages of using a group leader. Group leader confers with instructor prior to lab. period.

29 Roland W. Pinger, "Some Findings about Visual Aids in Engineering Education," *J. Eng. Educ.*, vol. 45, no. 8, pp. 652–3, April, 1955.

The author discusses the problems in using slides as visual aids. He claims that the aid is seldom worth showing unless home copy is furnished.

30 S. C. Hollister, "Importance of Engineering Science on Future of Profession," *Applied Mechanics Review*, vol. 8, no. 5, pp. 181–2, May, 1955.

Importance of mechanics in strengthening of engineering science; mechanics and math. needed to give tools for attacking problems from a fundamental point of view. Importance of this for modernizing design courses.

31 Eric J. Lindahl, "Some Suggested Changes and Shift of Emphasis in the Engineering Curriculum," *J. Eng. Educ.*, vol. 45, no. 10, p. 780, June, 1955.

Suggests that all students take same basic course rather than have service courses. Discusses textbook stuffing.

32 ASEE, "Report of Committee on Evaluation of Engineering Education," *J. Eng. Educ.*, vol. 46, no. 1, September, 1955.

The report itself should be read.

33 G. A. Hawkins, "Designing the Educational Program," *J. Eng. Educ.*, vol. 46, no. 3, pp. 241–6, November, 1955.

Analyzes engineers into 5 classes: 1. Engineer-scientist (5–10%), 2. Creative-design engineer (10–20%), 3. Functional engineer (40–50%), 4. Engineer-technician (10–20%), 5. Engineers in non-engineering work (5–10%). A good many of above are eventually executives, administrators, owners, etc. Elements in the design of curriculum are motivation, laws of learning, language, natural laws, general mode of analysis, laboratory experiences, properties of materials, skill in computation, knowledge of control, knowledge of industrial processes, appreciation of values, etc.

34 L. A. Finzi, "Uses of the Laboratory in the Teaching of Electric Machinery Courses," *J. Eng. Educ.*, vol. 46, no. 4, pp. 321–6, December, 1955.

Suggestions for more inspiring and imaginative use of machinery lab. than the usual "3-variable test." Also emphasizes co-ordination between lecture and lab. work, even if this means sometimes reducing lab. work to a demonstration.

35 Great Britain—Minister of Education, "Technical Education," White Paper, Her Majesty's Stationery Office, London, England, 1956.

Reviews the situation in the British Isles and compares it with USA, Russia, and Western Europe. "Technical education" refers to all technical education at all levels from tradesman and technician to professionally qualified engineers and scientists. Much of the discussion is irrelevant to our present interests, but pertinent comments are: (1) The British system where-

by a majority of engineers reach professional standing by part-time study while working, by a number of routes, and by a minority by full-time study is considered more flexible than the American. (2) Comparative figures show Russia to be educating far more engineers pro rata than any other country (280 per million), Britain next (220 per million), USA (136 per million), Western Europe (67 per million). Figures for pure science are Russia 56, Britain 105, Western Europe 48, USA not given. (3) Education of technicians and tradesmen in quantity and quality believed to be much better in Britain than in USA.

36 P. P. Love, "Criticism of Technical Education of Recently Qualified Engineers," *Inst. Mech. Engrs., Proc.* vol. 170, no. 3, pp. 127–36, 1956.

What's wrong with training and how to remedy it. Some thought is given to the question of scientific method of reasoning and fundamentals.

37 S. S. L. Chang, "Suggestions on How to Teach Engineering Sciences," *J. Eng. Educ.*, vol. 46, no. 5, pp. 456–7, January, 1956.

Engineering sciences should be given in one subject embracing (a) solid mechanics, (b) statistical properties of an aggregate of particles, (c) heat temperature, entropy, etc., (d) transfer of momentum, (e) properties of an aggregate of closely bound particles–elasticity, etc. In short, engineering sciences should be taught in two courses: 1. non-electrical sciences, and 2. electrical sciences.

38 R. C. Reid, "M.I.T.'s Engineering Practice School," *J. Eng. Educ.*, vol. 46, no. 5, pp. 441–5, January, 1956.

Oak Ridge Engineering Practice School set up in conjunction with AEC as a carefully-run industrial experience center for new graduates. "Course" lasts about 1 semester. Students work in teams of about 3 on actual plant problems, which have been selected as being: 1. educational 2. feasible. At end of each problem student must make report.

39 B. L. Goodlet, "How Mechanical Engineers Are Educated in Russia," *Engineering*, vol. 181, no. 4698, pp. 134–5, February 10, 1956.

This is a general survey of the course in mech. eng. One notable difference is the inclusion of extensive courses in workshop and the specialization in one field of mech. eng.

40 W. E. Reaser, and S. L. Soo, "Thermodynamics in Engineering Science," ASME Paper presented at Cleveland, Ohio, June 17–21, 1956.

Describes the approach and apparatus used at Princeton by the authors. Subject presented in fundamental scientific manner, authors believing no other subject has such value as exercise in reasoning and simple mathematics. Laboratory work co-ordinated with lecture and approached similarly, *not* as code testing exercises. Description and photographs of steam generator, heat exchanger, turbogenerator, surface condenser, air compressor, and assemblies of the above.

41 "Thick and Thin Sandwiches," *Engineering*, vol. 181, no. 4712, pp. 553–4, June 29, 1956.

Review of sandwich system (cooperative programs).

42 H. S. Arms, "American System of Education and Training of Mechanical Engineers," *Inst. Mech. Engrs., Proc.* vol. 171, no. 6, pp. 215–9, 1957.

Reviews American system. Study of *Who's Who in Engineering* shows definite correlation between fundamental nature of course done and high placing in *Who's Who*. A pre-occupation with practice goes with a low position in the list. Engineering practice is transi-

tory. The U. S. probably needs a system like the British Technical College system. *Extremely valuable article.*

43 A. F. Burstall, "Methods of Teaching Mechanical Engineering Subjects at British Universities," *Inst. Mech. Engrs., Proc.* vol. 171, no. 12, pp. 463–8, 1957.

Probing survey of teaching philosophy suggests training for creative ability—design, dissertation.

44 C. Jaeger, B. L. Goodlet, and A. L. L. Baker, "Comparison of Continental, Russian, and British Engineering Education," *Engineer,* vol. 203, no. 5272–3, p. 203, February 8, 1957.

Compares British, Continental and Russian systems. Continental and Russian systems tend to specialize (5½ year course) so that graduate is ready almost immediately for responsible work. British give shorter, more general course and leave the "breaking in" to industry. This latter is described as uneconomical and should be done by more post graduate work. Lab. work mentioned as important, but no detail given.

45 E. D. Howe, "Trends in Laboratory Instruction for Mechanical Engineering," *J. Eng. Educ.,* vol. 47, no. 7, pp. 565–7, March, 1957.

Gives definition of an engineer and states usually accepted objectives of laboratory work as: 1. teach use of instruments; 2. teach organization of tests; 3. techniques of analyzing data; 4. practice in presenting reports; 5. develop attitude of research worker. Considers objectives will tend more toward report writing and evaluation than toward manipulative skill.

46 R. A. Wheasler, and J. Liston, "Methods in Creative Design," *J. Eng. Educ.,* vol. 47, no. 9, pp. 750–5, May, 1957.

Authors believe that based on their experiences in aeronautical eng. at Purdue, creative design courses belong in senior year to provide synthesis aspects supplementing "fundamental" courses. Emphasize psychological aspects, choice of suitable projects, competition.

47 D. A. Dallamore, "Some Aspects Relating to Profession of Mechanical Engineering," *S. African Mech. Engr.,* vol. 6, no. 12, pp. 473–85, July, 1957.

Considerations relating to the training of engineers—comparison of university training in different countries.

48 Thomas H. Rockwell, "Increase Laboratory Effectiveness with Greater Student Participation," *J. Eng. Educ.,* vol. 48, no. 1, pp. 39–42, October, 1957.

This article suggests the use of a student lab. assistant in making a more dynamic lab. course. Students are encouraged to do creative thinking. Suggests modification of existing lab. both in procedure and physical apparatus.

49 F. L. Ryder, "Filling a Gap in Engineering Education," *J. Eng. Educ.,* vol. 48, no. 1, pp. 47–55, October, 1957.

Problem solving by whatever means works. Examples included.

50 W. Puckey, "Challenge of the "Dip-Tech," *Inst. Production Engrs., Journal,* vol. 36, no. 11, pp. 699–704, November, 1957.

Discusses the Dip-Tech and the situation in England. Philosophy of training, projects, etc.

51 J. D. Ryder, "Engineering Education—View Ahead," *Inst. Radio Engrs., Proc.* vol. 45, no. 11, pp. 1459–62, November, 1957.

Leaning towards fundamental science, place of math. in computer age. Engineering as distinct from science. Two aspects of math. particularly emphasized: (1) differential equations (2) statistical theory. Engineering is defined as science and art concerned with utilization of materials, energy and man. Elec. eng. curriculum based

on this philosophy in operation at Michigan State Univ. is described.

52 R. S. Frank, "Design Engineer in Industry," Soc. Automotive Engrs., Paper no. S37, Meeting November 21, 1957.

Lack of interest in design engineering due to misunderstanding methods at Caterpillar Tractor Co.

53 J. F. Calvert, "Impact of New Engineering Concepts on Engineering Education," *Elec. Eng.*, vol. 76, no. 12, pp. 1041–4, December, 1957.

New concepts of information, control, computing, as they affect educ. philosophy. More room needed for decision making, discovery, and creative engineering in curriculum.

54 C. B. Millikan, "Advanced Education and Academic Research in Aeronautics," *Royal Aeronautical Society, Journal*, vol. 61, no. 564, pp. 793–809, December, 1957. Also abstract in *Engineering*, vol. 184, no. 4778, October 4, 1957.

How to meet the need for "scientific engineers." A critical analysis of the undergraduate curriculum in aeronautical eng. Gives the relationship between government research agencies and the university.

55 ASEE: "Objectives and Educational Programs in Nuclear Engineering Education," *J. Eng. Educ.*, vol. 48, no. 4, pp. 316–25, January, 1958.

Review of effects on and requirements of universities and other institutions. Objectives and educational programs in nuclear engineering education.

56 R. Lemlich, "A Plea for the Simple Experiment," *J. Eng. Educ.*, vol. 48, no. 5, p. 385, February, 1958.

The author suggests that more time should be alloted to the basic principles and less time to operation of machinery through the use of simple experiments. Suggests a write up of results for research report for publication in a journal rather than industrial report.

57 L. V. Bewley, "Reorientation in Engineering Education," *J. Eng. Educ.*, vol. 48, no. 7, pp. 497–503, March, 1958.

Reorientation of eng. activities so that those allied by theory and practice and which depend upon the same background, basic training and disciplines, shall constitute a div. of engineering. Detailed account of suggested curricula and physical layout of lab. etc.

58 D. W. Lewis, "A Plan for Integrating Courses," *J. Eng. Educ.*, vol. 48, no. 7, pp. 559–61, March, 1958.

The student would be introduced to a scale model of an industrial enterprise upon entering college. He would be introduced to its general structure and then its components. Then after selecting his course, he would constantly refer to the model while working in the curricula. Inspection trips to applicable plants would be arranged also to stimulate student interest.

59 A. V. Loughren, "The Crisis in Education," *IRE Transactions on Education*, vol. E-1, no. 1, pp. 6–7, March, 1958.

Crisis is one of staff, as a result of low salaries. Novel solution is to alter tax laws so that approved gifts are deducted from tax payments instead of taxable income.

60 C. W. Richards, "The Rejuvenation of a Materials Testing Laboratory," *J. Eng. Educ.*, vol. 48, no. 7, pp. 562–7, March, 1958.

The emphasis has been extended to individual project type of experiments after the few carefully chosen basic experiments have been introduced to the student. The results indicate more student interest.

61 W. F. Seibert, "A Brief Report and Evaluation of Closed-Circuit Television Instruction in Mechanical Engineering," *J. Eng. Educ.*, vol.

48, no. 7, pp. 538–44, March, 1958.

Some conclusions: Student achievement was the same. Student response was good but disadvantages were evident—interest, inability to discuss questions, etc.

62 G. C. Meyerhof, "Impressions of Visit to Some Universities in Western Europe," *J. Eng. Educ.*, vol. 48, no. 8, pp. 594–6, April, 1958.

England, Holland, West Germany and Switzerland—general philosophy of education.

63 N. H. Ceaglske, "Coordination of Classroom and Laboratory Instruction in Process Dynamics Control," *J. Eng. Educ.*, vol. 48, pp. 755–9, May, 1958.

The objectives of the course on control are mentioned along with some specific laboratory experiments including: "1. Difficulties encountered in steady state measurements including calibration of instruments; 2. Dynamic measurements—a. Transient response; b. Frequency response; 3. Experimental determination of control system parameters from: a. steady state data b. transient response data frequency response data; 4. Operation of a control system, comparing results with calculated responses." Includes some idea of description and cost of apparatus.

64 "A Study of the Content of the Engineering Curriculum," Second Progress Report of the Curriculum Study Committee, Department of Engineering, University of California, Los Angeles, May 15, 1958.

A significant self-study in which the courses in the unified curriculum are examined. The information presented to students is organized in general classification of I. Principles; II. Laws; III. (a) Concepts, (b) Percepts, (c) Definitions; IV. (a) Methods and Modes of Analysis, (b) Skills; V. Tools; VI. Factual Data; VII. Applications. Individual courses are analyzed regarding their contribution to the classifications.

65 Simon Ramo, "A New Technique of Education," *IRE Transactions on Education*, vol. E-1, no. 2, pp. 37–42, June, 1958.

Visualizes future educational institutions in which all routine operations of teaching—dull memorizing, testing, grading, etc.—are done by machines, leaving only high-level activity to teacher. Foresees a new profession, the "teaching engineer." Points out that proposals are expensive. Very stimulating.

66 S. Seely, "Whither Electrical Engineering Education," *IRE Transactions on Education*, vol. E-1, no. 2, pp. 34–7, June, 1958.

Formulates philosophy applicable to all branches of eng, educ. Excellent article.

67 J. L. Stewart, "Crisis in Engineering Education," *IRE Transactions on Education*, vol. E-1, no. 2, pp. 55–61, June, 1958.

Mentions numerical inferiority of U. S. output of engineers, but considers more serious the inferiority in quality. Factors in this are fetish for universal educ. and unwillingness to admit that all men have not equal mentality; poor faculty caused by low salaries, tenure, inbreeding; federal gov't. allocation of research contracts which draw good people from university. Poor faculty creates vicious circle tending to further downgrading. Recommendations for remedy made mainly changes in federal spending habits.

68 P. K. Weimer, "Automatic Teaching Device," *Inst. Radio Engrs., Transactions on Education*, vol. E-1, no. 2, pp. 51-3, June, 1958.

"Automatic" teaching device presents information and tests students in controlled feedback relationship. The author gives a general proposal for such a machine and points out advantages as well as limitations.

69 ASEE, "Report on Enginering Sciences," *J. Eng. Educ.*, vol. 49, no. 1, pp. 33–91, October, 1958.

Committees report what they consider are basic topics in mechanics of solids, mechanics of fluids, transfer and rate processes, thermodynamics, electrical sciences, nature and properties of materials, engineering analysis and design. Topics should be illustrated by lab. experiments or demonstrations. Hence article itself should be consulted in designing curricula of lab. courses.

70 "Engineering Analysis and Design," from "Report on the Engineering Sciences," *J. Eng. Educ.*, vol. 49, no. 1, pp. 77–91, October, 1958.

Extremely significant report. Function of the undergrad. engineering program is the establishment of the bases for future learning and problem-solving activity, not the conveying of factual technological background. Emphasizes modes of thinking of engineering analysis and design—synthesis, analysis and evaluation.

71 Lee Harrisberger, "Machine Design at North Carolina State College," *Machine Design and Manufacturing Bulletin*, a publication of the Mechanical Engineering Division of ASEE, vol. 23, no. 1, November, 1958.

Describes course offerings at North Carolina State College. Philosophy based on emphasis of fundamentals, but the understanding of fundamental laws must be taught by continually subjecting student to realistic project situations where compromising decisions must be made with no single answer.

72 V. A. Babits, "Science and Engineering Education: Europe—U.S.A." *IRE Transactions on Education*, vol. E-1, no. 4, pp. 110–116, December, 1958.

Babits is European-educated and has been 30 years in educ. in Europe and U.S.A. He compares the systems. Considers there is no cause for alarm in U.S. system since it produces pro rata more first-class scientists than European. Best 10–15 U. S. schools unsurpassed anywhere. Accredited schools are on about same level as European. Non-accredited schools are worse. Two things need remedy in U. S.: (1) poor pay of faculty, (2) pressure from "front office" on creative workers which stultifies their efforts. Failure rates in university course—Netherlands 50%, France 1%, Russia 15%.

73 T. L. Martin, and G. M. Russell, "New Directions in Electrical Engineering Education," *IRE Transactions on Education*, vol. E-1, no. 4, pp. 107–110, December, 1958.

Authors consider changes in curriculum are responses to feedback system. System has time lag of about 8 years in error signal. Signal that we are deficient in physics has just hit us. Authors predict that the next signal will be that we are short on statistics-information theory-systems engineering. It is systems that distinguish the engineer from the physicist. Basic ideas are (1) energy (2) materials (3) information. Attack the old "monolithic" curriculum.

74 J. D. Ryder, "Educational Castles in the Air," *IRE Transactions on Education*, vol. E-1, no. 4, pp. 104–6, December, 1958.

Traditional boundaries between departments—civil, elec., mech., etc.—are now anachronistic. Proposes degrees should be given by study in number of areas from departments grouped according to subject matter.

75 J. A. Pope, "Technological Research," *Inst. Mech. Engrs., Proc.* vol. 173, no. 20, pp. 547–554, 1959.

Analyzes in diagrammatic form the "areas" occupied by pure scientific research, applied science, technological development and their relation to communal needs and practice. Discusses statistics of future training needs in both university and high school.

76 J. E. Arnold, "Mechanical Design at Stanford," *Machine Design and Manufacturing Bulletin,* a publication of the Mech. Eng. Division of ASEE, vol. 25, no. 2, January, 1959.

Description of courses and design philosophy at Stanford. Courses emphasize analysis, synthesis and evaluation. Believes that usual coverage emphasizing mechanisms, dynamics, strength of materials, should be expanded to include products and systems, some aspects of aesthetics and marketing and an understanding of the electro-mechanical and human problems associated with open- and closed-loop systems.

77 A. H. Burr, and R. M. Phelan, "Machine Design at Cornell University," *Machine Design and Manufacturing Bulletin,* a publication of the Mech. Eng. Division of ASEE, vol. 25, no. 3, February, 1959.

Course offerings from an extensive and comprehensive list are described in detail. The undergraduate curricula are 5 years in length. General philosophy behind the teaching is that the student should have instruction and practice in the correlation and application of pre-requisite subjects; that he become familiar with machine parts; that he learn to analyze and to create simple machines; and that he learn certain principles of design distinct from the principles of mechanics.

78 *You and Your Students,* prepared by a Faculty Committee, Massachusetts Institute of Technology, revised February, 1959.

An excellent manual for teachers based on principles of recognized soundness. Treats topics such as educational teamwork, the learning process, objectives, technique of teaching, testing, grading, counseling and bibliography. Available from ASEE or Office of Publications, MIT, Cambridge 39, Mass. (45 pages)

79 L. E. Grinter, "Survery of Current Changes That Are Modernizing Engineering Education," *J. Eng. Educ.,* vol. 49, no. 7, pp. 559–72, March, 1959.

Report on the changes in eng. educ. since report of ASEE 1954–55.

80 J. S. Johnson, "Philosophy of Engineering Education," *J. Eng. Educ.,* vol. 49, no. 7, pp. 580–7, March, 1959.

Fundamentals, not details important. Definition of eng. with designation of types of work. Summary of philosophies given in article.

81 R. L. McFarlan, "Role of the Laboratory in Engineering Education," *IRE Transactions on Education,* vol. E-2, no. 1, pp. 23–27, March, 1959.

Summarizes comments from a conference on the above. Points are: 1. Young teacher can learn to teach by running alternate lab. and conference–lecture sessions. He should be given freedom in lab. courses. 2. Lab. courses should be given status and importance they deserve, not treated as chores for graduate-instructors. 3. Care needed in progressing from cook-book-type job to job which challenges student. 4. Importance of writing clear reports greatly stressed.

82 B. F. Skinner, "Teaching Machines," *IRE Transactions on Education,* vol. E-2, no. 1, pp. 14–22, March, 1959.

Describes Pressey's machine of the 1920's and its limitations, then describes another machine being used at Harvard. Shows many advantages of the machine and relates them to modern psychology of learning.

83 J. B. Hartman, "Machine Design at Lehigh, Part I," "Further Comments on the Future of Machine Design, Part II," *Machine Design and Manufacturing Bulletin,* a publication of the Mechanical Engi-

neering Division of ASEE, vol. 25, no. 4, May, 1959.

Part I describes the machine design instructional program at Lehigh University. Part II points out the shortcomings in traditional type of programs. Some specific suggestions are made for *vitalizing* the courses and the instructors.

84 W. J. Fahey, "Undergraduate Laboratories—Some Comments on Efficient Use of Student's Time," *IRE Transactions on Education*, vol. E-2, no. 3, pp. 75–77, June, 1959.

To reduce the usual complaint about the length of report-writing time, students are required to report in detail in writing on only 2 experiments and merely to submit data, calculations and conclusions for others. *But* they are required to report verbally (about 15 minutes) and individually on a randomly sampled 40% of other jobs, without warning. This causes students to understand work and helps the instructor to really evaluate student.

85 G. A. Hawkins, E. C. Thoma, and W. K. Lebold, "A Study of the Purdue University Engineering Graduate," *J. Eng. Educ.*, vol. 49, no. 10, pp. 930–47, June, 1959.

Analysis of records, occupations, achievements, salaries, and opinions of Purdue graduates from 1911 to 1956. Sample of about 5,000 people from total population of about 24,000. Relative importance of subjects in curriculum in their opinions are: 1. English composition, 2. speech, 3. properties of materials, 4. laboratory (eng.), 5. engineering sciences—mechanics and electrical, 6. drawing, etc. 7. fluids and thermo., etc. Other conclusions relate to occupation, status, value of higher degrees, etc.

86 J. H. Keenan, "Education in Transition," *Mech. Eng.*, vol. 81, no. 76, p. 76, June, 1959.

Education of the mechanical engineer stressing the scientific approach.

87 R. F. Mager, "Preliminary Studies in Automated Teaching," *IRE Transactions on Education*, vol. E-2, no. 3, pp. 104–7, June, 1959.

Reports successful tests in using Skinner-type machines for teaching subjects like algebra, kinetic theory, etc. to children 12–14. Suggests method may have far-reaching uses.

88 W. A. Blackwell, and H. E. Koenig, "A Combined Machinery and Control Systems Laboratory," *IRE Transactions on Education*, vol. E-2, no. 4, pp. 128–34, September, 1959.

Stresses importance of considering machines as part of a system, and hence shows advantages of combining electrical machines and systems labs. into one. This is done by using *small* machines and breadboards with measuring instruments. Considers that lab. should go further and include hydraulic and pneumatic machines. Pictures of torquemeter, typical breadboard set-ups, lists of equipment. Small scale not only reduces capital cost but reduces setting-up price and gives flexibility.

89 R. F. Schwartz, "Laboratory: Its Scope and Philosophy," *IRE Transactions on Education*, vol. E-2, no. 4, pp. 120–22, September, 1959.

A restatement of objectives.

90 "Experimental Engineering," vol. I, Engr. 4A, Introduction to Engineering Systems, University of California, Los Angeles, Revised September, 1959.

Notes written for a course intended to provide beginning engineering students an introduction to the general procedure for studying the behavior of engineering systems. First section outlines course content, second deals with measurements and descriptive statistics. Sections 3, 4 and 5 describe experiments to be performed. Sixth section contains selected reading list. Section on measurements and statistics extremely interesting and

important for early introduction of important concepts.

91 E. M'Ewen, "Training of Engineers," *Engineer*, vol. 208, no. 223, September 11, 1959.

Philosophy of engineering—emphasis on more practical knowledge for engineering lecturers.

92 "Education at Florida Presbyterian College," *Bulletin of Florida Presbyterian College*, vol. 1, no. 9, October, 1959.

This is a new college of liberal arts with unique quality program emphasizing independent learning. Laboratories: "Students engaged in courses in the natural sciences will undertake programs of laboratory practice and research. Traditional manual exercises and experiments will be minimized. Emphasis will be placed on acquiring the ability to distinguish theory and experimentation, understanding principles, exploring the advantages and limitations of methods, critical reading, and evaluation of experiments, the necessity of design and individual analysis. In the science area, the small laboratory meeting takes the place of the discussion groups and provides an excellent environment for the interchange of ideas and methods."

93 W. N. Findley, "A New Look at Machine Design at Brown University," *Machine Design and Manufacturing Bulletin*, a publication of the Mech. Eng. Division of ASEE, vol. 26, no. 1, October, 1959.

Describes a newly developed machine design course at Brown Univ. Guiding principles: students learn mainly through what they do for themselves. Recognizes that while machine design may involve almost every aspect of engineering knowledge, 3 degrees of comprehensions are recognized: familiarity, facility and mastery.

94 Lee Harrisberger, "Introducing Library Research into Machine Design," *Machine Design and Manufacturing Bulletin*, a publication of the Mech. Eng. Division of ASEE, vol. 26, no. 1, October, 1959.

Describes design projects which encourage library research.

95 A. T. Murphy, "Program in Engineering Science for All Engineering Students," *Elec. Eng.*, vol. 78, no. 10, pp. 1006–11, October, 1959.

"A program of undergraduate engineering education built around a core of courses that stress the fundamental understanding of engineering sciences for all students. It is hoped that this modification will foster creative ability." Elimination of "service" courses. Thorough job on what is attempted. Course descriptions given. *Structure of Eng. Education*—University core requirements (32%), Engineering core requirements (52%), Specialized courses (16%).

96 R. K. Pefley, and R. I. Murray, "Experience in Teaching Thermodynamics and Fluid Mechanics as an Integrated Course," *J. Eng. Educ.*, vol. 50, no. 1, pp. 77–80, October, 1959.

Advance the usual arguments for integration. Consider their experiment at Santa Clara successful.

97 Massachusetts Institute of Technology, "Interim Report of the Committee on Engineering Design," November 3, 1959.

Under Carnegie grant, committee studied problem. Comments and conclusions were: (1) Present curricula tend to emphasize single-answer problems, and analysis, which does not correspond to real life. (2) Synthesis, open-ended or comprehensive problems should be included, which should include experimental checking in lab. (3) Problem of getting high-calibre students interested in design is discussed. Traditional tendency is to regard design as too "low-brow." (4) Value of design experience and internship shown. (5) In relation to no. 3, some design work should be in every year of course, including freshman, and (6) Suit-

able labs. should be provided. Two sample projects quoted.

98 G. L. Goglia, "Textbook Needs of the Undergraduate Lab." *Heat Power News and Views,* vol. XV, no. 52, December, 1959.

Engineering lab. philosophy: "I feel that a laboratory textbook with a plan of attack consistent with the current educational objectives has yet to be written."

99 J. B. Hartman, "Problems and Trends in Machine Design Instruction," *Machine Design and Manufacturing Bulletin,* a publication of the Mech. Eng. Division of ASEE, vol. 26, no. 2, December, 1959.

Recognizes criticism of current status and content of machine design courses. Recommends reorganization based on clearly defined objectives; integrated and sequential development of material; fresh approach in textbooks; increased use of computers (analog and digital); introductions of a statistical approach in reliability concepts, etc.; introduction of more experimental laboratory work related to design; emphasis of snythesis and creative approach. Recognizes need to develop and train teachers in the field.

100 J. J. Ryan, "Mechanical Engineering Design," *Machine Design and Manufacturing Bulletin,* a publication of the Mech. Eng. Division of ASEE, vol. 26, no. 2, December, 1959.

Author believes that in design, basic things only must be known. Utilization of this material in practice must be guided by proper reference material. Laboratories should be available to design courses, with student constructing his own apparatus where possible. Students should develop problems of their own interest and practice inventiveness.

101 R. R. Slaymaker, "An Unconventional Undergraduate Course in Machine Design," *Machine Design and Manufacturing Bulletin,* a publication of the Mech. Eng. Div. of ASEE, vol. 26, no. 2, December, 1959.

Author states that learning progresses from specific experiences to generalized conclusions. Proposes a course entirely of actual industrial case studies, representing real design situations. Goal of the course, in the opinion of the author, is to give the student confidence by showing him that he can solve engineering problems with the fundamental tools he already possesses.

102 G. A. G. Fazekas, "Some Thoughts on Undergraduate ME Curricula," Brooklyn, New York, 1960.

A thorough consideration of American undergraduate ME curricula: its present status and future requirements.

103 "Proceedings of 1959 Invitational Conference on Testing Problems," Princeton Educational Testing Service, pp. 39–86, 1960.

104 Fred Landis, "The Undergraduate Teaching of Heat Transfer," *Heat Power News and Views,* ASEE, vol. 15, no. 54, pp. 3–7, January, 1960.

Suggests more instrumentation experiments in laboratory.

105 A. D. Dunk, "Engineering vs. Design," *Machine Design and Manufacturing Bulletin,* a publication of the Mech. Eng. Division of ASEE, vol. 26, no. 3, February, 1960.

The author notes that "engineering" and "design" are synonymous and that undergrad. training should provide student with broad concepts of mathematics and the ability to apply it to engineering problems, and should develop a broad and deep understanding of the physical world so that he can solve new problems.

106 C. N. Henshaw, "Machine Design Instruction," *Machine Design and Manufacturing Bulletin,* a publication of the Mech. Eng. Division of ASEE, vol. 26, no. 3, February, 1960.

The objectives of machine design courses include correlation of knowledge obtained in previous courses, introduction to practical considerations, and provision of an opportunity to exercise ingenuity.

107 J. S. McNown, "The Research Flavour," *IRE Transactions on Education*, vol. E-3, no. 1, pp. 2–3, February, 1960.

Describes stimulus given to lab. class by giving elementary research problems in fluid mechanics, e.g. (1) examine changes in shape of jets from non-circular orifice from the point of view of design of fountains (2) Investigate process of pouring from bottles from the point of view of speed and absence of gulping.

108 J. B. Hartman, "Some Approaches toward Solutions to Problems in Instruction in Experimental Mechanical Engineering and Design Courses," paper presented to Advisory Conference on Mechanical Engineering Experimental Laboratory curricula, sponsored by National Science Foundation, Washington, D. C., March 25, 1960.

Paper describes some new approaches to laboratory instruction now being put into effect at Lehigh University. Program emphasizes less "cook book" type of testing of commercial machinery and more creative effort on part of students in planning, designing, and executing experiments. Future plans for laboratory and design courses are discussed with work to be supported by a grant from the National Science Foundation.

109 Edward B. Fry, G. L. Bryan, and J. W. Rigney, "Teaching Machines: An Annotated Bibliography," Supplement 1 of the *AV Communication Review*, vol. 8, no. 2, spring, 1960, published by the Dept. of Audio-Visual Instruction, National Education Association, 1201 16th St., Washington 6, D. C.

110 Jack T. Kimbrell, "The Machine Design Laboratory," *Machine Design and Manufacturing Bulletin*, a publication of the Mech. Eng. Division of ASEE, vol. 26, no. 4, April, 1960.

General philosophy of teaching machine design lab.

111 J. N. MacDuff, "The Future of the Machine Design Laboratory," *Machine Design and Manufacturing Bulletin*, a publication of the Mech. Eng. Division of ASEE, vol. 26, no. 4, April, 1960.

A series of experiments in the design area which serve to extend both experimental and analytical skill.

112 J. Modrey, "Putting Machine Design into Orbit," *Machine Design and Manufacturing Bulletin*, a publication of the Mech. Eng. Division of ASEE, vol. 26, no. 4, April, 1960.

A perceptive critical evaluation of the present state of machine design taught in our undergraduate curricula. Author states that design courses should emphasize synthesis and have an integrating role. Computers and applied probability theory give promise for a major breakthrough.

113 T. A. Bickart, "A Look at the New Electrical Engineering Laboratory Program at The Hopkins," *IRE Transactions on Education*, vol. E-3, no. 2, pp. 36–41, June, 1960.

New program begins with fairly easy spoon-fed work accompanied by detailed manual and progresses in final years to work with very little detailed instruction, requiring student to do his own thinking. Nature of lab. manual changes progressively. Equipment emphasizes plug-boards, plug-in components and plug-in subcircuits.

114 Gordon B. Carson, "New Horizons for Experimental Investigation in the Mechanical Engineering Curricula," *J. Eng. Educ.*, vol. 50, no. 10, June, 1960.

Reports formation of steering committee and states aims and first conclusions.

115 L. Trefethan, "Information Concepts and Laboratory Work at Tufts University," June 10, 1960.

A radically new approach to the whole curriculum, making information concepts the touchstone and basis of everything. Laboratory becomes place for gathering and studying information. All faculty members participate in lab. in areas where they are interested. Amount and kind of lab. work by student depends on individual faculty members. Endeavors are made to carry on projects.

116 A. A. Lumsdaine, and Robert Glaser, *Teaching Machines and Programmed Learning: A Source Book*, Dept. of Audio-Visual Instruction, National Education Association, 1201 16th St., Washington 6, D. C., June, 1960.

Said to be the most comprehensive and authoritative reference work on automated instruction. It will bring together the basic papers by leaders in development of teaching machines and programmed exercises during the last four decades.

117 L. M. K. Boelter, "Professional Engineering Education," ASME Paper 54-IRD-11, presented at Instruments and Regulators Conference, Philadelphia, Penna., September, 1954.

An important paper, with valuable definitions of terms, including engineering, design function, education, research and development. Discusses content of an engineering curriculum for meeting complex problems of the future.

118 EUSEC, "Engineering Education and Training," Paris, France, September, 1957.

USA contribution to EUSEC Conference. Includes glossary on terms used and organization of engineering education in USA; discussion of selection for admission to USA engineering schools; practical training, post-degree education criteria for, and professional recognition in USA.

119 EUSEC, *Proceedings of the Third EUSEC Conference on Engineering Education*, Paris, France, September, 1957.

Presents summary of conclusions and recommendations, as well as 6 general reports.

120 G. Reethof, "Control Technology as Unifying Tool in Engineering Education," ASME Paper no. 58-A-199, presented at Annual Meeting, 1958.

Author expresses opinion that control engineering courses in the engineering curriculum have a unifying potential in teaching student to apply math. techniques and material from technical courses to the solution of engineering problems.

121 J. H. Westcott, "An Experiment in Control Engineering Education," ASME Paper no. 58-A-164, presented at Annual Meeting, 1958.

Describes a proposed solution at Imperial College, England, for coordinating instruction in control engineering. Scheme involves establishing a central nucleus of control experts under aegis of an existing department. They will conduct research and organize courses in control engineering for all engineering students.

122 John D. Gill, "A Guiding Philosophy for Mechanical Engineering Laboratories and Some Examples for the Internal Combustion Engines Laboratory in Particular," unpublished memorandum, July 15, 1959.

Excellent statement of guiding philosophy to be applied in planning and equipping an entirely new laboratory at the University of Miami. Core of conclusion is "that the primary purpose of the laboratory is to provide enlightenment of the student in methods of exploration, to bring him into a creative atmosphere where instruments, test machinery and advice are available to encourage intelligent scientific testing." Emphasizes importance of men and in-

struments. Includes organization chart on laboratories.

123 "Propulsion, Research and Instruction," *Aeroplane,* vol. 84, no. 2163, pp. 11–16, January 2, 1953.

A good general description of the College of Aeronautics, Cranfield, including curricula design demonstration room.

124 H. Thal-Larsen, "Course of Instruction in Systems Engineering," *J. Eng. Educ.,* vol. 48, no. 9, pp. 742–54, May, 1958.

Outline of course on process control and instrumentation. Gives a thorough idea of teaching problems encountered in developing the subject matter.

125 "Interim Report of the Engineering Science Curriculum Study," Massachusetts Institute of Technology, October 14, 1951.

Report summarizes the state of thinking of a 20-member study group. An Engineering Science Curriculum for M.I.T. is outlined and discussed. It emphasizes training in the pure and applied sciences. The role of the laboratory is discussed in detail. States that laboratory program seeks to avoid routine, stylized experiments. Staff problem for a suitable lab. program is critical.

126 P. K. Stein, "Measurement Engineering, Science or Technology?" *Strain Gage Readings,* vol. II, no. 6, Feb.–Mar., 1960, Stein Engineering Services, Phoenix, Arizona.

Describes a course in measurements taken by engineering students at Arizona State University. Some description of lab. experiments and instruments.

127 EUSEC, "British Contribution to the Third EUSEC Conference on Engineering Education," Paris, France, September, 1957, published by Inst. of Mech. Engrs., London, England, 1958.

Topics include glossary, general education, selection for admission to eng. schools, education at university level, practical training, criteria for professional recognition and post degree education.

128 "Experimental Engineering," Vol. III, Engr. 4 C, Lecture Notes and Notes for Laboratory Experiments, Dept. of Engineering, University of California, Los Angeles, September, 1954.

Lecture notes and experiments related to properties of materials including solids and fluids. Some experimental stress analysis experiments.

129 "Experimental Engineering," Vol. VII, Engr. 104 CD, University of California, Los Angeles, Revised September, 1956, Third Ed., September, 1959.

General instructions and notes for experiments in the senior laboratories. Experiments are in the fields of heat and mass transfer, internal combustion engines, thermal and luminous radiation, advanced stress analysis, fluid flow, analog computers, production, power plant test and projects.

130 *S.E.S.A. Manual on Experimental Stress Analysis Techniques,* (Prelim. Edit.), Society for Experimental Stress Analysis, Cambridge, Massachusetts, 1959.

Covers the three most important tools of experimental stress analysis: (1) bonded wire strain gages; (2) brittle lacquer; (3) photoelasticity.

131 "Experimental Engineering," Vol. VI, Engr. 104 B. Revised January, 1960, University of California, Los Angeles.

Notes for laboratory experiments in the junior laboratory. Introduction to rotating machines, especially electrical machines, and simple systems. Instructions for most of the experiments are complete and detailed with step by step procedures.

132. S. J. Kline, "The Use of Laboratory in Fluid Mechanics Instruction for National Science Foundation Conference, September, 1960."

Describes program developed at Stanford University. Lists possible objectives of laboratory teaching, noting that "only in laboratory work (or design courses) can we give assignments which approach in complexity and scale the real engineering situation with which the student will be faced upon graduation." Objective of program is to begin preparation of mechanical engineers to operate in research and development areas.

133 F. Kreith, "An Experiment in Teaching Engineering Research and Creativity to Gifted Undergraduates."

Experiences of the author at University of Colorado in a preliminary experiment in "teaching" research and creative thinking, under sponsorship of National Science Foundation were sufficiently encouraging to warrant describing it, to indicate its strong and weak points so that others interested in similar programs could benefit from the experiences gained.

134 H. E. Stockman, "Use of Educational Aids in Electronics," *IRE Transactions on Education*, vol. E-3, U.3, pp. 89–99, September, 1960.

A comprehensive survey of general educational aids including: reading machines, teaching machines, film strips, closed loop T.V. etc. The paper reviews the present philosophy of our eng. educational system and suggests many changes in our attitude toward engineering education,—a thought provoking article.

135 W. R. Hatch and A. Bennet, "Research on Teaching in Engineering and Related Subjects," *J. of Eng. Educ.*, vol. 51, no. 1, p. 48, Oct., 1960.

A general review of a number of articles on: 1. problem-oriented approaches to teaching, 2. more effective utilization of teaching resources, 3. new principles for curriculum construction, and 4. prediction of student performance.

136 S. T. Poage, "Simulators for Industrial Engineering Undergraduate Laboratories," *J. of Engr. Educ.*, vol. 51, no. 1, pp. 45–47, October, 1960.

Describes the use and development of inexpensive services to simulate real processes in ind. engr. Defines the purpose that the simulator should fulfill.

137 H. A. Foecke, "Educational Literature Displayed at Conference on Development of Young Engineering Faculties," *J. of Eng. Educ.*, vol. 51, no. 2, pp. 93–97, November, 1960.

A short bibliography on teaching philosophy including reviews on the various booklets, manuals, pamphlets, books, periodicals, etc. The author does not claim to be exhaustive in the field but rather assembles a display of representative literature in the field.

138 C. J. Freund, "The Artist Engineer," Paper presented at Mechanical Engineering Department Heads Session, Winter Annual Meeting, A.S.M.E., New York, November 30, 1960.

The engineer's increasing identification with science tends to make him forget his professional function of "ministry to the people." This ministry, the art of engineering, must be emphasized lest the profession lose its character.

139 A. H. Burr, "A New Look at an Old Course, The Principles of Machine Design." Paper presented at Mechanical Engineering Department Heads Session, Winter Annual Meeting, A.S.M.E., New York, November 30, 1960.

Instruction in machine design may be grouped under important principles and rules, seldom written but frequently applied to balanced and reliable designs. These principles are illustrated and discussed.

140 J. B. Reswick, "Report on First Engineering Design Education Conference Held at Case Institute of

Technology, September, 1960." Paper presented at Mechanical Engineering Department Heads Session, Winter Annual Meeting, A.S.M.E., New York, November 30, 1960.

Conference held for purpose of bringing together people from colleges and universities who have been discussing and formulating recommendations for innovations in engineering design education. Considerable attention given to definition of engineering design. A proceedings of the conference is in production and copies will be available upon request at no cost.

141 K. R. Wadleigh, "Some Problems in Undergraduate Instruction." Paper presented at Mechanical Engineering Department Heads Session, Winter Annual Meeting, A.S.M.E., New York, November 30, 1960.

Reliance upon the scientific method is primary objective of undergraduate engineering laboratory. Emphasis on need to develop an integrated staff moving freely between laboratory and classroom, making the laboratory a focal point of learning.

142 J. B. Hartman, "Progress Report on Mechanical Engineering Laboratory Studies Supported by National Science Foundation." Paper presented at Mechanical Engineering Department Heads Session, Winter Annual Meeting, A.S.M.E., New York, November 30, 1960.

Discusses work in progress at Lehigh University. Development of solutions to instructional problems in experimental mechanical engineering and design courses recognizes their interdependence and need for broad considerations of educational philosophy. Bibliographies have been developed on this subject along with descriptions of laboratories, teaching aids, experiments related to design, etc. Lists laboratory activities in three categories; familiarization, demonstration and exploration (or "project" or research). Suggests use of movies and teaching aids preferable for demonstration of principles.

143 G. L. Goglia, and J. F. Lee, "Progress Report on Experimental Mechanical Engineering Laboratory Studies Supported by National Science Foundation." Paper presented at Mechanical Engineering Department Heads Session, Winter Annual Meeting, A.S.M.E., New York, November 30, 1960.

Report delineates philosophy of study and reports in detail on six experiments which have been developed. Reports on specific experiments include statement of objectives, description of apparatus, and discussion of performance.

144 A. K. Johnston, "Thoughts on Engineering Education," Newcastle University College, Australia, October, 1960.

Observations on American engineering education. Comparisons with British and Australian systems. Interesting view of the future in engineering education.

HAZEN INTERIM PRESIDENT OF ROBERT COLLEGE, ISTANBUL

Alfred Ogden, Chairman of the Board of Trustees of Robert College of Istanbul, Turkey, has announced the appointment of Dr. Harold L. Hazen as Interim President of that institution, following the resignation of Dr. Duncan S. Ballantine, for reasons of ill health.

Dr. Hazen's appointment to the presidency of Robert College, which includes the American College for Girls, also in Istanbul, is for an interim period during which the Board of Trustees will have an opportunity of considering various candidates for the presidency on a permanent basis.

AEC EDUCATIONAL ASSISTANCE ACTIVITIES

The Atomic Energy Commission has reorganized its educational assistance activities which provide aid to nonprofit educational institutions in establishing or expanding nuclear curricula.

Mr. John C. Cera has been designated Special Assistant to Mr. A. Tammaro, Assistant General Manager for Research and Industrial Development, and will act as Coordinator of Nuclear Education and Training. This reorganization establishes a focal point within the AEC for the many and varied interests in nuclear education and training. Mr. Cera formerly was Chief, Education and Training Branch in the Division of Reactor Development.

The Division of Reactor Development equipment-grant, materials-loan, faculty-training and special-fellowship programs and the Office of Isotope Development equipment-grant program have been transferred to the new office. In the future correspondence on these activities should be directed to:

John C. Cera, Coordinator of
Nuclear Education and Training
U. S. Atomic Energy Commission
Washington 25, D. C.

Mr. Cera will also be responsible for the overall coordination of university-relations educational activities of the AEC including the development of policy, plans, programs, procedures and reporting associated with these activities.

The Commission has extended through June 30, 1964, its programs of assistance for nuclear education in U. S. nonprofit educational and medical institutions. These programs, some of which were originally scheduled to be terminated by June 30, 1961, are intended to keep the United States in the forefront of support for scientific and technological education in the areas of the physical and life sciences and engineering related to atomic energy. The financial level of support for these programs will be determined annually through normal budgetary practices. Assistance in the United States will be continued on the same basis as in the past, except in one of the programs.

In the reactor technology program, no further grants will be made for the construction or purchase of teaching reactors. However, the Commission will continue to loan to qualified institutions without charge source and special nuclear materials for use in teaching reactors. The change in this program was based on the desirability of aiding more universities and colleges, the need for providing comprehensive undergraduate study in the nuclear sciences, the existence of other federal programs for support of research reactors which are also useful in laboratory courses, and the high cost of teaching reactors compared with other teaching devices such as subcritical assemblies and reactor simulators.

The training equipment grant program will be changed from the furnishing of equipment for use in the education of reactor engineering specialists to the furnishing of equipment useful in general nuclear education in colleges of arts and sciences in addition to engineering colleges. The purpose of this change is to strengthen higher education in the physical and engineering sciences by providing equipment for upgrading existing courses in chemistry, physics, metallurgy and engineering, and to aid in the establishment of new courses such as radiochemistry, chemical processing and nuclear safety. Typical items which may be requested under this program are nuclear particle detection devices, pulse height analysers, radioisotopes, subcritical assemblies and neutron sources.

The objective of the training equipment grant program is to aid qualified U. S. engineering schools and colleges of arts and sciences in obtaining nuclear laboratory

and demonstration equipment and associated nuclear materials useful in teaching fundamental subjects relating to atomic energy. Undergraduate and graduate laboratories will be strengthened by this program which will emphasize teaching as distinct from research, though the equipment may frequently serve both purposes.

The Commission's programs of educational assistance include: financial grants for the purchase of nuclear equipment for teaching in the life sciences, physical sciences and engineering; loans of source material and special nuclear materials without charge for use in demonstration and formal laboratory experiments; fellowships in nuclear science and engineering, health physics, industrial medicine and industrial hygiene; faculty training for college teachers in basic and advanced nuclear technology, presently conducted in conjunction with the American Society for Engineering Education; faculty training in radiation biology for high school and college teachers, presently conducted in cooperation with the National Science Foundation; faculty training for college teachers in the use of radioisotopes and safe handling techniques, conducted in conjunction with the National Science Foundation; cooperative programs conducted by the Commission's national laboratories which provide university faculty and students an opportunity to use the special facilities of the laboratories; courses in the use of radioisotopes offered at the Oak Ridge Institute of Nuclear Studies; operation of the International Institute of Nuclear Science and Engineering at the Argonne National Laboratory, conducted as part of the Commission effort to aid in the nuclear education of engineers and scientists from abroad; courses in reactor supervision and reactor hazards at the Oak Ridge National Laboratory, primarily for scientists and engineers from abroad; operation of the Puerto Rico Nuclear Center to assist Spanish-speaking students in nuclear science and engineering.

In its program of financial assistance for university research reactors, the Commission will continue to loan nuclear materials for fuel and start-up sources, and provide assistance for fuel fabrication and chemical reprocessing of the spent fuel elements. It is expected that the National Science Foundation will continue to assume Federal responsibility for providing assistance toward the construction of such reactors.

Since 1956 the Commission has made equipment grants of about $18,500,000: $13,800,000 to 125 institutions in the program for reactor technology; $3,800,000 to 213 institutions in the program for the life sciences, and $900,000 to 76 institutions in the program for radioisotope technology in the physical sciences. The Commission also has loaned about $11,000,000 worth of nuclear materials to many of these institutions.

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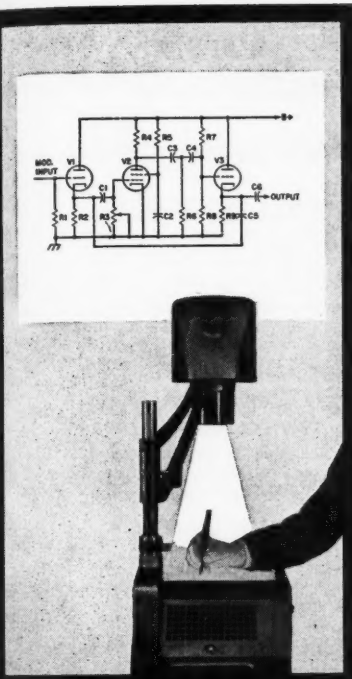

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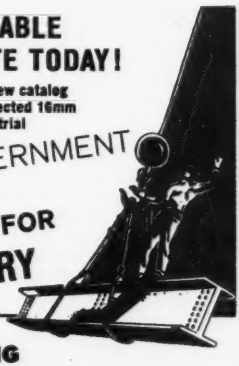

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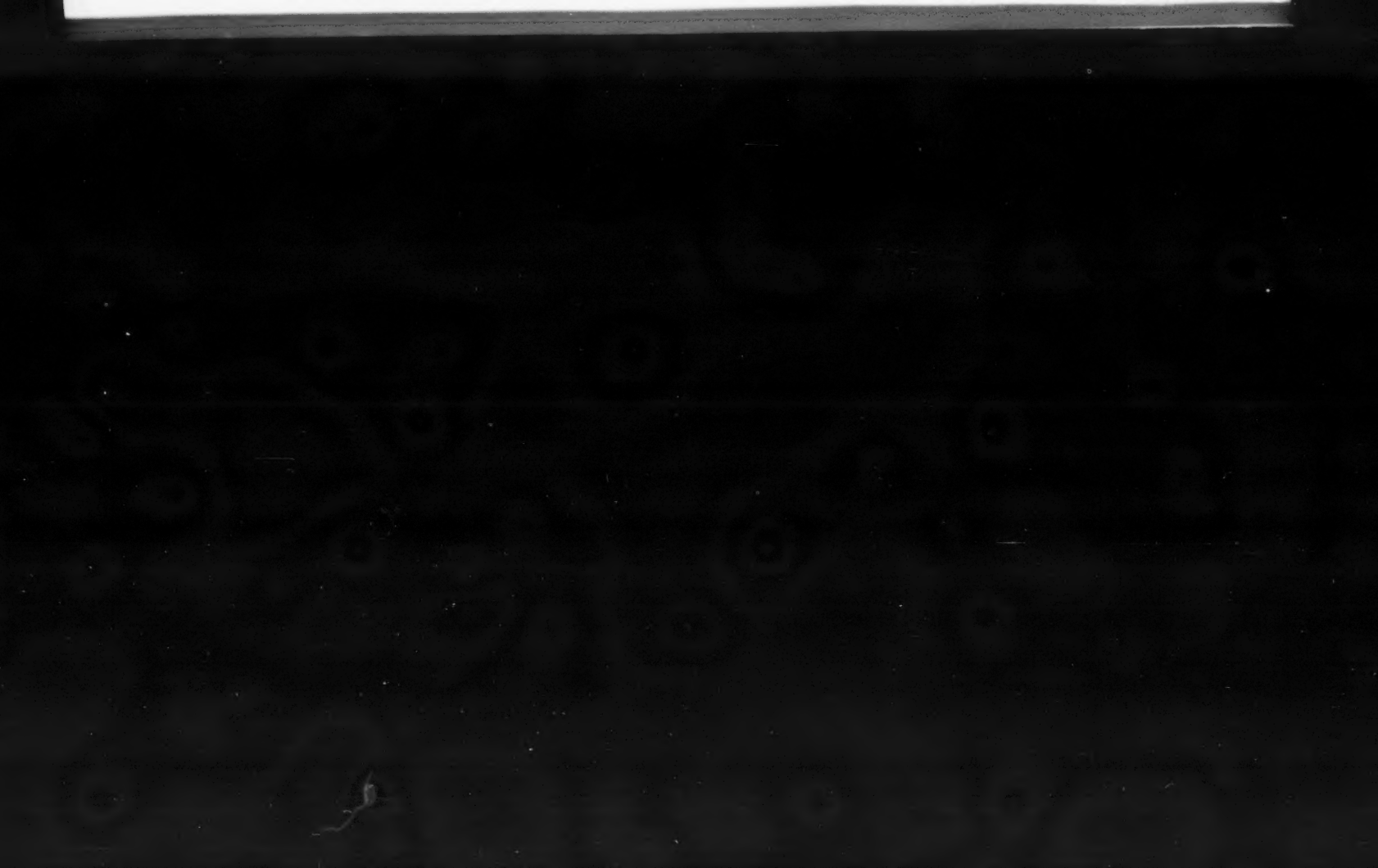

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